



NEW YORK AIR NATIONAL GUARD

HEADQUARTERS 106th AIR RESCUE GROUP
SUFFOLK COUNTY AIR NATIONAL GUARD BASE
WESTHAMPTON BEACH, NEW YORK 11978-1294

June 23, 1994

Robert Wing , Section Chief
Federal Facilities
United States Environmental Protection Agency
26 Federal Plaza
New York, NY 10278

Dear Mr. Wing,

The report entitled *Evaluation of 2-Butanone in Groundwater Samples* was issued as a final document in March of 1992 to United States Environmental Protection Agency (USEPA), New York State Department of Environmental Conservation (NYDEC), New York State Department of Law (NYDOL) and Suffolk County Department of Health Services (SCDHS). Comments were received from the NYDOL. The included Document is the response to those comments as well as additional sampling data (Appendix O) provided by SCDHS for the Fire Training Area (FTA). The conclusions reached are as follows.

The Evaluation of 2-butanone in Groundwater Samples report demonstrates that the presence of 2-butanone in groundwater samples collected from several of monitoring wells during past sampling events is attributable to the use and insufficient rinsing of a small volume of commercial-grade methyl hydrate which was used as a decontamination fluid for groundwater sampling equipment. The methyl hydrate was used in accordance with work plans prepared for site activities and reviewed by appropriate agency personnel prior to implementation. It is our belief that additional numerical modeling is unnecessary given the nature and distribution of site-related groundwater containments at the FTA. The groundwater plume modeling results presented further support our recommendation to proceed with a Decision Document at the FTA.

We believe the issue of 2- Butanone in groundwater samples at the FTA has been thoroughly addressed. With the State's concurrence we wish to proceed to a Decision Document for the site. Feel free to contact me at (516) 288-7349 if you have any questions or concerns.

Sincerely,

SEAN M. WALTER
Environmental Manager

cc:

M. Chen, NYDEC
J. PIM, SCDHS
G. Gribbar, ANGRG
P. Primi, NYDOL





ASEA BROWN BOVERI

6943-61

May 7, 1993

Mr. Dwight Robertson
Martin Marietta Energy Systems, Inc.
Hazardous Waste Remedial Actions Program (HAZWAP)
831 Tri County Boulevard
Oliver Springs, TN 37840

Subject: Response to comments from the New York State Department of Law regarding the *Evaluation of 2-Butanone in Groundwater Samples* report

Dear Mr. Robertson:

The purpose of this letter is to address issues raised by the New York State Department of Law (NYSDEL) during review of the *Evaluation of 2-Butanone in Groundwater Samples* report (March 1992). The concerns are stated in a letter from Patricia Primi dated 05 Nov 92 to Mr. Sean Walter at the 106th Rescue Group/EMO New York Air National Guard Base. Attachment A contains a chronological history of activities that took place at the FTA during Site Characterization activities. Attachment B contains the response to NYSDOL comments. NYSDOL comments are provided in Attachment C. Back-up material, affidavits, and calculations are provided in Attachments D through N. Note, because many of the personnel involved in the sampling activities are currently in the field, fax copies of signed affidavits have been provided. Original copies will be provided when personnel return from the field.

In a recent phone conversation (28 April 93) with Sy Robbins at the Suffolk County Department of Health Services (SCDHS), Mr. Robbins indicated that additional groundwater quality information had been collected on 12 April 93 from three newly installed monitoring wells at the FTA. The three wells, FP-1, FP-2 and FP-3, are roughly co-located with wells MW-103, MW-107A and MW-101A, respectively. Mr. Robbins indicated that 2-butanone was not detected in any sample. Results of the SCDHS sampling are provided in Appendix O. The SCDHS groundwater sampling results should bring to an end the issues raised by the NYSDOL. AB-ES believes that the issue of 2-butanone in groundwater samples at the FTA has been thoroughly addressed. AB-ES hopes, upon review of the supplemental information provided in this letter, that the NYSDOL will concur with our recommendations to proceed with a Decision Document at the FTA.

Sincerely,

ABB ENVIRONMENTAL SERVICES, INC.

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Gary Shearer, P.E.
Project Manager

cc: T. Smith

D. Ertz

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ATTACHMENTS

- A. Chronology of Events during site characterization at the Fire Training Area
- B. Response to comment letter to NYSOL's comments
- C. NYSOL's comments on *Evaluation of 2-Butanone in Groundwater* report
- D. Affidavit: Authorization from HAZWRAP to switch solvents from isopropanol to methyl hydrate
- E. Affidavit: Authorization from HAZWRAP to switch from methyl hydrate to Liquinox
- F. Proposal for Statement of Work date 10 October 1990 outlining scope of well purging experiment
- G. Photographs showing collection of decontamination liquids
- H. Billing invoice for 5-gallons of isopropanol
- I. Affidavit: ABB-ES soil sampling crew stating procedures used for use, handling and disposal of isopropanol.
- J. Affidavit: ABB-ES groundwater sampling crew stating sampling/decontamination procedures that lead to 2-butanone contamination detected in Fire Training Area wells
- K. Drawdown, well volume and stagnation point calculations
- L. Field notes from Round 5 groundwater sampling (i.e., pH, temperature, specific conductance and purge rate measurements)
- M. Solute (Plume 3D) and Jury Model output with supplementary calculations
- N. Copy of paper submitted by Jury, et al. in *Water Resources Research*
- O. Results of SCDHS groundwater sampling at the FTA.

ATTACHMENT A
CHRONOLOGY OF EVENTS
SUFFOLK COUNTY AIR NATIONAL GUARD
FIRE TRAINING AREA
SITE CHARACTERIZATION

To clarify the sequence of events leading up to, during, and following the site characterization activities at the Fire Training Area (FTA), a chronology of events has been prepared and is presented below.

1. The FTA was used by the United States Air Force for fire training activities from 1943 to 1970. Waste aircraft fuels and solvents were placed in a bermed, unlined concrete pit.
2. After 1970 the FTA was used by the Air National Guard (ANG) Suffolk County Airport and several local fire departments for fire training activities. The FTA was used by all or some of these groups until August 1986 when its use was discontinued. Waste fuels used in fire training exercises were stored on-site in bulk in a large tank and were drained to the bermed area as needed.
3. In 1982 preliminary investigations were conducted by the ANG following concerns regarding the potential impact of waste fuels used during training exercises on groundwater. Preliminary investigations indicated contaminants at low concentrations in groundwater near the FTA. The preliminary results were never formalized, but the ANG initiated a Remedial Action Plan (RAP) for further investigation.
4. The RAP outlined activities to be conducted in a subsequent Site Characterization Investigation. ABB Environmental Services (ABB-ES, formerly E.C. Jordan) was contracted (Contract 96B-97386) by Martin Marietta Energy Systems, under the Hazardous Waste Remedial Actions Program (HAZWRAP) to conduct the Site Characterization Investigation.
5. ABB-ES prepared a Site Characterization Investigation work plan in 1986 that was reviewed by the ANG, HAZWRAP, United States Environmental Protection Agency (USEPA), Suffolk County Department of Health Services (SCDOHS), New York State Department of Environmental Conservation (NYSDEC), and New York State Department of Law (NYSDOL). Comments from these agencies

were incorporated into the final work plan, as appropriate, and the work plans reissued in accordance with the terms of the contract. There were no comments pertaining to use and disposal of decontamination liquids.

6. The scope of the work plan was to complete soil borings and collect surface soil samples to characterize possible soil contamination at the site. Monitoring wells were also installed to characterize the quality of the groundwater upgradient and downgradient of the FTA. Monitoring well sampling was to be conducted in two rounds (Round 1 and 2), first in April 1987, then again in July 1987. According to the scope of work, the results of the soil sampling and for Round 1 of the groundwater sampling were to be summarized in a site characterization report; the results of the Round 2 groundwater sampling effort were to be provided in an addendum to the site characterization report.
7. In accordance with industry practice and to reduce the potential for cross contamination between sampling location, drilling equipment and sampling devices were to be thoroughly washed with water, isopropanol, and Liquinox, prior to and following sampling.
8. Isopropanol does not contain 2-butanone, the substance that is the subject of the investigation described in the following paragraphs and in Attachment B.
9. The Site Safety Plan, an attachment to the work plan, estimated that 85 gallons of isopropanol would be used as a decontamination solvent. The 85 gallons was an estimate understood to be the maximum volume of isopropanol anticipated to be used.
10. An industry accepted practice at the time of development of the work plans was to discharge decontamination fluids directly to the ground surface. Hence, the work plans stated that decontamination fluid was to be disposed of on the ground surface.
11. The initial Site Characterization drilling program started in February 1987.
12. Split spoons are the primary tool used for the collection of soil samples in borings and as a result, constitute the equipment most commonly decontaminated. During site characterization activities, split spoons were first washed in a soap/water solution and then rinsed with tap water. The spoons were then rinsed with dilute isopropanol over a container and rinsed again over the container with deionized

water. The container with dilute isopropanol and water was then poured into a 55-gallon drum to be disposed of by the base. These procedures are summarized in attached affidavits.

13. Contrary to what was stated in the 1986 Work Plan, isopropanol and associated rinse water used for drilling equipment decontamination were not disposed on the ground surface during drilling and sampling activities conducted in 1987. Instead, the decontamination fluid was containerized in a 55-gallon drum. This change was not incorporated into the work plan.
14. According to available project documentation (i.e., project invoices), only 5 gallons of isopropanol were used during drilling and soil sampling activities.
15. Subsequent to the drilling program and prior the first round of groundwater sampling (April 1987), ABB-ES switched its decontamination solvent from isopropanol to methyl hydrate. Therefore, methyl hydrate was used as a sampling device decontamination solvent for the first groundwater sampling event in April 1987 (Round 1). ABB-ES received verbal authorization from HAZWRAP to make the switch in solvents (see affidavit in Attachment D).
16. Methyl hydrate was also used for two subsequent groundwater sampling rounds completed in July 1987 and February 1989 (Rounds 2 and 3); decontamination fluids generated during groundwater sampling efforts were discharged to the ground surface in the vicinity of the well.
17. The decontamination procedures followed during groundwater sampling Rounds 1, 2, and 3 (April 1987, July 1987 and February 1989, respectively), consisted of placing the submersible pumps used to purge the monitoring wells in a 2-inch diameter decontamination vessel. The vessel was filled with approximately one to two liters of methyl hydrate (typically diluted) and the pump turned on. The contents of the pump and tubing were discharged to the ground nearby. The pump was subsequently rinsed with several liters of deionized water by following the same procedures.
18. Stainless steel bailers used to collect groundwater samples during Rounds 1, 2, and 3 were decontaminated using pressure sprayers containing a 1:1 mixture of methyl hydrate and deionized water. Rinsate was discharged to ground surface.

19. In April 1987, a Site Characterization Report was prepared that indicated presence of 2-butanone in several wells, upgradient and downgradient of the FTA. The report recommended an additional investigation to determine the cause and distribution of 2-butanone.
20. A Final Draft Site Characterization Report was submitted to HAZWRAP, ANG, U.S. Air Force (USAF), NYSDEC, USEPA, SCDHS and NYSDOL for review in October 1987. Comments received from the SCDHS, NYSDOL, USEPA and USAF were responded to in the *Response to Comments Site Characterization Report*, issued in June 1989. No comments were received regarding the use or disposal of decontamination fluids. The Final Characterization Report was issued in June 1989.
21. In November 1988, as a result of recommendations made in the Final Site Characterization Report (see Paragraph 19), ABB-ES issued an Additional Investigation Work Plan for a supplemental investigation at the FTA to determine the extent of 2-butanone contamination.
22. The scope of the supplemental investigation was to complete up to 10 screened-auger borings to collect vertical groundwater samples in upgradient locations from the FTA and to determine whether there were any upgradient sources of 2-butanone. Within those borings, at least four monitoring wells would be installed for confirmation of the screened auger drilling to characterize groundwater upgradient of the FTA. Supplemental investigations were completed in October 1989.
23. Results of the February 1989 groundwater sampling event (Round 3) indicated the presence of 2-butanone in upgradient and downgradient wells. Methyl hydrate was the decontamination solvent used during this sampling event. Equipment was decontaminated in a manner as described Paragraphs 17 and 18.
24. Following the February 1989 groundwater sampling effort and prior to the initiation of the screened auger drilling (October, 1989), ABB-ES began to suspect that methyl hydrate used in equipment decontamination might have been the source of 2-butanone. ABB-ES requested approval from HAZWRAP's Quality Assurance Officer to stop using methyl hydrate as a decontamination solvent at the FTA. HAZWRAP's QA Officer gave ABB-ES verbal permission to discontinue use of a decontamination solvent for the October 1989 field effort, which included Round 4 groundwater sampling (see affidavit in Attachment E).

25. The ten screened-auger borings and four monitoring wells were installed in October 1989 as part of the supplemental Site Characterization activities. The ten borings, which were located upgradient of the FTA, were installed to identify potential source of 2-butanone identified during the first three rounds of groundwater sampling. Field screening of groundwater samples collected from 9 of the screened auger borings did not indicate evidence of 2-butanone contamination. Through field screening, 2-butanone was detected in one boring (corresponding to well MW-201) at a depth of 65 feet, however, subsequent confirmatory sampling at MW-201 did not verify these findings.
26. A fourth round of groundwater samples was collected in December 1989, including the four new upgradient wells. Methyl hydrate was not used as a decontamination fluid. However, it is believed that the backup pump (pump #2) that was transported to the site and used for purging well MW-202 may have been decontaminated at another site using methyl hydrate prior to its mobilization to the FTA. Pump #1, which was the pump used to purge all other wells sampled during Round 4, was cleaned with copious amounts of water prior to its use. Unlike Pump #1, Pump #2 never underwent the thorough rinsing with water because it was intended to be used only in the event of failure to pump #1. Pump #1 failed to operate following its use at MW-201 due to near freezing temperatures. The backup pump (Pump #2) was lowered into well MW-202 to begin purging the well (Well MW-202 was installed during the supplemental investigation in October 1989). It is believed that residual contamination in Pump #2 may have introduced 2-butanone into the well casing of MW-202. Upon completing sampling at MW-202, pump #1 was operational and was used throughout the remainder of the sampling round. Pump #2 was not used again on this site.
27. Results of the fourth round of groundwater sampling indicated the presence of 2-butanone in MW-107B, and ethanol (primary constituent of methyl hydrate) in MW-101A and MW-202. Wells MW-107B and MW-202 are downgradient and MW-101A is upgradient of the FTA.
28. ABB-ES suspected that the 2-butanone (and ethanol--introduced through trapped residuals in the pump) was present in the stagnant water columns of the contaminated monitoring wells. ABB-ES devised a method for removing the residual 2-butanone from the well casing. It was intended that this procedure would provide data to verify or disprove the theory that the source of the 2-butanone was the stagnant water columns. The method consisted of

recirculating and purging several volumes of water in and from the well, respectively. ABB-ES believed that when the stagnant water was removed, and the inside of the monitoring wells were "washed" of all residual contaminants, the concentration of 2-butanone in the wells would no longer be detected. ABB-ES made a request to HAZWRAP to conduct a well purging experiment in a last round of well sampling. ABB-ES received a Statement of Work from HAZWRAP and subsequently prepared a proposal outlining the groundwater sampling procedures that would be performed at the FTA (see Page 3-19, Section 3.2.14.2 in Attachment F). Authorization to conduct the well purging experiment was received from HAZWRAP in September 1991.

29. A final set of groundwater samples were collected at selected locations during October 1991. The experimental sampling/purging procedures were focussed on well MW-107B, but other wells were also sampled. Liquinox and deionized water were used as a decontamination liquid throughout the sampling procedures. The test was initiated by purging three volumes of water from the well (standard protocol for well sampling). Following the initial purging, a groundwater sample was collected with a stainless-steel bailer. After collecting the first sample, the well was purged again for approximately 10 minutes except that the discharge water was directed back down the well. This recirculation was conducted to rinse the well casing and agitate (and mix) the water column so that a more representative sample could be collected. After recirculating for 10 minutes, seven well volumes were purged from the well to the ground surface. A final groundwater sample was subsequently collected. Results of this event indicated that 2-butanone was present in the sample collected prior to recirculation, however, 2-butanone was not present in the sample collected following the recirculation. It is unlikely that the boundaries of a contaminant plume would be limited to the area impacted by groundwater withdrawal. Therefore, the 2-butanone detected prior to recirculation and well purging was concluded to be from the stagnant water in the well casing as opposed to another source.
30. Concurrent with the well purging experiment, ABB-ES performed laboratory analysis of the methyl hydrate used equipment decontamination during groundwater sampling Rounds 1, 2, and 3. ABB-ES learned that 2-butanone was present in the methyl hydrate at concentrations ranging from 2-3% by volume.
31. The results of the purging experiment formed the basis for a report entitled *Evaluation of 2-Butanone in Groundwater Samples*. The report was issued final

in March of 1992 to USEPA, NYSDEC, NYSDOL, and SCDHS. No comments were received from USEPA or SCDHS.

32. The ANG received comments to the 2-butanone report in November 1992 from NYSDOL.

RESPONSE TO COMMENTS BY NEW YORK STATE DEPARTMENT OF LAW
DATED 05 NOV 92 ON THE
EVALUATION OF 2-BUTANONE IN GROUNDWATER SAMPLES

As detailed by the chronology, ABB Environmental Services, Inc., (ABB-ES [formerly E.C. Jordan, Co.]) was retained under contract to Martin Marietta Energy Systems (Contract 96B-97386) to perform soil and groundwater investigations at the New York Air National Guard/106th Rescue Group (Base) at the Francis S. Gabreski Airport in Suffolk County New York (Suffolk County Air National Guard Base). This investigation required the installation and sampling of soil borings and monitoring wells.

To reduce the potential for cross contamination between sampling locations, prior to and following sampling events, drilling and sampling equipment was thoroughly decontaminated. A concern has been raised regarding the handling and disposal of organic solvents used for decontamination procedures possibly resulting in groundwater contamination at the Base. This concern was discussed in the *Final Site Characterization Report* (June, 1989), as well as in the report entitled *Evaluation of 2-Butanone in Groundwater Samples* (March, 1992). These reports were submitted to HAZWRAP, the ANG, the Base, the United States Air Force (USAF), NYSDEC, SCDHS, NYSDOL and USEPA Region II for review prior to finalizing. Comments received from NYSDOL, SCDHS USEPA and the USAF on the Site Characterization Report were addressed in the *Response to Comments Site Characterization Report*, which was issued in June 1989. NYSDOL was the only agency to submit comments on the *Evaluation of 2-Butanone in Groundwater Samples* report.

The *Evaluation of 2-Butanone in Groundwater Samples* report concluded that 2-butanone in wells at the Fire Training Area was attributable to the use of methyl hydrate for decontamination fluid during groundwater sampling efforts. As presented in Appendix B of the *Evaluation of 2-Butanone in Groundwater Samples* report, analysis of the commercial grade of methyl hydrate used on-site indicated that it contained between 2 and 3 percent 2-butanone by volume. The report demonstrated that residual 2-butanone in pumps used for well purging was introduced into well casings prior to groundwater sampling and that these "trapped residuals" were the source of 2-butanone in groundwater samples collected at the Base Fire Training Area. At the concentrations detected, it was concluded that 2-butanone did not represent a potential threat to groundwater supplies.

The ABB-ES response to additional comments of the New York Department of Law (NYSDOL) to these conclusions follows. This response is structured to address what is understood to be

the general comments and concerns as well as "specific matters to be addressed" outlined in a November 5, 1992 letter from Ms. Patricia Primi of NYSDOL to Mr. Sean Walter of the New York Air National Guard/106th Rescue Group/EMO, (Attachment C).

Response to General Comments

Comment: In Paragraph 1 of Page 1 of the November 5, 1992 letter, and as explained by the example cited in Paragraph 1 of Page 2, the reviewer indicates that some of the report's arguments and conclusions are either contradicted or inadequately supported by available information. She suggests that, in addition to the residual methyl hydrate trapped in submersible pumps providing a method for the introduction of methyl hydrate into groundwater samples, methyl hydrate may have been introduced through disposal of decontamination liquids to the ground surface that were generated during drilling and equipment decontamination as described in both work plans prepared for the site.

Response: Disposal of a large volume of decontamination fluids to the ground surface could potentially provide a means of introducing 2-butanone into the groundwater. However, as detailed below, only a small volume (less than 20 gallons) of methyl hydrate used during groundwater sampling activities completed during the period of February 1987 to February 1989 was disposed onto the ground surface. The decontamination fluids used during drilling activities were not disposed to the ground surface, but rather containerized for disposal by the Base. In addition, methyl hydrate, which contains 2 to 3% 2-butanone by volume, was not used as a decontamination fluid during installation of any of the monitoring wells or soil borings at the Fire Training Area. These activities would have generated the greatest quantities of decontamination fluids. Only five gallons of isopropanol was used as decontamination fluid for these activities. The isopropanol, at most, contains only trace quantities of 2-butanone. Additional information on the use and handling of decontamination fluids follows.

The type and volume of decontamination fluids varied over the course of the site investigations. The 1986 work plan indicated that 85 gallons of isopropanol would be used as a decontamination solvent during drilling activities covered by the plan. The 1988 Work Plan indicated that 6 gallons of methyl hydrate would be used. During the 1986 investigation, isopropanol was used as a decontamination fluid during drilling and soil sampling activities. However, contrary to the 1986 Work Plan, only 5 gallons of isopropanol, which contains only trace concentrations of 2-butanone, and not 85 gallons was used. Methyl hydrate was not used during the drilling activities associated with the 1988 field investigation as proposed; Liquinox and water were substituted for methyl hydrate because of the concern for sample contamination by 2-butanone. Methyl hydrate was, however, used for the first three rounds of groundwater sampling

completed in April and July 1987 and February 1989. Approximately 1 to 2 liters of methyl hydrate was used to decontaminate purge pumps after each use. An additional 400 milliliters of methyl hydrate and deionized water (diluted 1:1, i.e., 200 ml of methyl hydrate equivalent to a 1 to 2% 2-butanone by volume) was used to decontaminate the stainless steel bailers used during groundwater sampling. During groundwater sampling, decontamination fluids were discharged to the ground surface in the vicinity of the wells being sampled. Four wells were purged with a submersible pump during sampling Round 1 in April 1987 (approximately 8 liters of methyl hydrate was used, based on a total of 2 liters used per well including decontamination of the bailer), 11 wells during Round 2 in July 1987 (approximately 22 liters of methyl hydrate used), and 22 wells during Round 3 in February 1989 (approximately 44 liters of methyl hydrate used). The maximum volume of methyl hydrate that could have been disposed of on the ground therefore is approximately 74 liters (approximately 20 gallons) during all three rounds of groundwater sampling. The information presented above is confirmed by the attached affidavits as well as by field equipment warehouse invoices (see explanation below).

Regarding decontamination fluid disposal, contrary to the work plans, not all decontamination fluids were disposed to the ground surface. The isopropanol and deionized water used as cleaning/rinsing fluids during the installation of monitoring wells and/or soil borings during the site characterization activities in February 1987 were disposed of in a 55-gallon drum. However, the Liquinox and water, which was used as a primary wash for sampling equipment prior to the solvent/water rinse, was disposed of on the ground surface. Liquinox does not contain 2-butanone. Following drilling, the drum containing isopropanol and deionized water was transferred to the Base Civil Engineer for disposal. Affidavits from field personnel attesting to these practices are attached; photographic documentation of a decontamination station setup at the Base is provided in Attachment G. The decision to containerize drilling and decontamination fluids during the site characterization activities was made shortly before initiation of field activities. The decision was not formally incorporated into the site work plans.

Decontamination fluids (Liquinox and water -- see paragraph 24 of the chronology) associated with supplemental site characterization activities completed in October 1989, and decontamination fluids (methyl hydrate and deionized water) associated with groundwater sampling Rounds 1, 2, and 3 completed in April and July 1987, and February 1989, respectively, were discharged directly to the ground surface. Purge water from monitoring well sampling (Rounds 1 through 5) was also discharged directly to the ground surface. These discharges occurred in the vicinity of each well being sampled (Figure 1).

As detailed in the site characterization report, approximately 30 feet of unsaturated soil separates the ground surface and the water table at the FTA. Soil, through the process of adsorption, acts as a natural filter for contaminants. Given the depth to groundwater (30 feet), and the dilute

2-butanone concentrations (2-3% by volume) and volumes of the methyl hydrate decontamination fluid that were discharged to the ground at the separate well sites (22 sites total) over a two year period, it is virtually impossible to introduce 2-butanone into the groundwater via the pathway suggested by the reviewer. Recall that the total volume of methyl hydrate containing only 2-3% by volume of 2-butanone, did not exceed 20 gallons. This equates to a total of only 0.6 gallons of 2-butanone disposed at 22 sites during the two year period that methyl hydrate was used as a decontamination fluid.

Comment: In Paragraph 2, Page 2, the reviewer indicates that the work plans provide a basis for approximating the mass of contaminant introduced to the groundwater during each of the field investigations. The reviewer contends that the mass of 2-butanone involved was limited, and that the main mass of 2-butanone was probably introduced in the spring of 1987, providing a starting point for fate and transport analysis. The reviewer's reasoning is based on the 1986 Work Plan that calls for the on-site use of 85 gallons of decontamination fluid, rather than the 1988 work plan that calls for 6 gallons of decontamination fluid to be used during the supplemental investigation.

Response: As stated above, the 1986 Work Plan states that 85 gallons of *isopropanol* (not methyl hydrate) was to be taken to the site for use as a decontamination fluid for sampling equipment. The volume of isopropanol listed in the Work Plan is not the volume used during field sampling activities. The volume of isopropanol that was *actually* taken to the field for use during soil boring and monitoring well installation activities was 5 gallons—not 85 gallons. This is supported by the fact that similar quantities of decontamination solvent (6 gallons) were proposed for use in the supplemental investigations. In addition, a billing invoice that was received (from ABB-ES equipment warehouse personnel) shortly after the field effort concluded (Attachment H) indicates that 5 gallons of isopropanol was supplied to the job. The job number (#5096-02), which is listed on the invoice, was associated with the field investigation at the FTA. Please note that soil boring logs in the Site Characterization Report Volume II Appendices have the same job identification number. ABB-ES requires that a record of all project-specific purchases be maintained. Internal review of previous and subsequent invoices indicate that no other chemicals used as a decontamination solution were purchased for soil boring and well installation activities.

Moreover, all of the isopropanol (as well as the deionized water used to rinse the isopropanol) used onsite during the initial site characterization activities completed in April 1987 was containerized in a 55-gallon drum and disposed of by the base civil engineer. Affidavits verifying these statements are provided in Attachment I. It should also be noted that, the industrial-grade isopropanol used as a decontamination fluid contains only trace concentrations

of 2-butanone; therefore, even if the volumes used were disposed to the ground surface a significant mass of contamination would not be introduced.

Relative to the supplemental investigations, the 1988 Work Plan issued in November 1988, presents a more realistic estimate of the anticipated volume of solvent that was to be used during supplemental field sampling activities. The 1988 Work Plan indicates that 6 gallons of methyl hydrate were to be taken into the field for use as equipment decontamination fluid during the supplemental site investigation. However, methyl hydrate was never used in the 1989 drilling and soil sampling activities completed during the supplemental investigation. Just prior to mobilization, in October 1989, E.C. Jordan Co. received information disclosing the presence of 2-butanone in methyl hydrate (see paragraphs 24 and 30 of the chronology). At that time, E.C. Jordan Co. requested and received verbal permission from HAZWRAP to substitute Liquinox for methyl hydrate as the equipment cleaning solution. An affidavit confirming these statements is provided in Attachment E.

In summary, the only possible source of 2-butanone was during the first three rounds of groundwater sampling activities. A maximum of approximately 20 gallons of methyl hydrate was discharged to the ground surface (with minor amounts discharged to the groundwater) during these activities. The total volume of 2-butanone associated with this release to the ground surface is approximately 0.6 gallons (based on 2 to 3% 2-butanone in methyl hydrate by volume x 20 gallons). This would result in approximately 8,880 gm (4.02 pounds) of 2-butanone discharged to the ground surface. It should be noted however, that the volume of methyl hydrate used during the three rounds of groundwater sampling completed over a two year period was dispersed at 22 separate groundwater sampling locations (Figure 1). Because of the thickness of the unsaturated zone (approximately 30 feet) and the effects of adsorption and dispersion, it is virtually impossible to generate the kind of contaminant plume the reviewer is suggesting.

Comment: In Paragraph 3 of Page 2 the reviewer indicates that it is not surprising that the groundwater sampling data did not disclose a single, simple, easily definable contaminant plume. She contends that the conclusions that 2-butanone is not a "genuine aquifer contaminant" are not adequately supported. The reviewer indicates that the contention that 2-butanone concentrations declined following cessation of methyl hydrate use at the site is not supported by the fact that elevated concentrations of constituents of methyl hydrate i.e., 2-butanone, ethanol and ethyl acetate continued to be detected in downgradient Well 107B, for the entire period between April 1987 and October 1991. The reviewer attributes an increase in the concentration of ethanol and ethyl acetate at Well 107B between sampling rounds 4 and 5 to contaminant plume migration toward and past this downgradient monitoring point and not to the trapped residuals theory presented in the report. Similarly, the reviewer attributes the observed declines in 2-butanone

concentrations at more up-gradient wells after round 3 to the migration of dissolved contamination past the available monitoring points.

Response: Relative to the increase in ethanol and ethyl acetate concentrations in MW-107B during rounds 4 and 5, it is important to keep in mind that ethanol and ethyl acetate are Tentatively Identified Compounds (TICs), and as such, calibrations are *never* performed for these compounds under the Contract Laboratory Program. It is impossible to ascertain the actual concentration without running calibration standards. In addition, relative comparisons of data (such as the one drawn by the reviewer) should only be done if the instrumentation and time of analysis are similar, or if the numbers are *grossly* different. Because there are so many variables involved with TIC data, a trend analysis should only be done for calibrated compounds such as 2-butanone. The trend for the concentration of 2-butanone in MW-107B is clearly decreasing indicating that the well bore is gradually being purged of 2-butanone during each sampling event, thus supporting the "trapped residual" theory.

Comment: In Paragraph 1 of Page 3 the reviewer points out that ethanol was detected in Well 202 in December 1989, despite the fact that this well was installed and sampled eight months after the last on-site use of methyl hydrate. The reviewer indicated that the ethanol detected in the sample from Well 202 could not have resulted from "trapped residuals", but rather was indicative of ethanol contamination in the groundwater.

Response: The occurrence of ethanol in well MW-202 is attributed to the use of a submersible pump that contained residual methyl hydrate. This occurrence is described in Item 26 of the chronology. The submersible pump (pump #1) that was to be used for well purging was cleaned thoroughly at our equipment warehouse in Portland, Maine with Liquinox and water prior to mobilizing to the field. A backup pump (pump #2) was also brought to the site in the event of mechanical problems with pump #1. Although the decontamination procedures used on pump #2 cannot be verified, it is believed that it was decontaminated with Liquinox, deionized water, and methyl hydrate at another site prior to its mobilization to the Base. Because pump #2 was a backup pump, it never underwent a second cleaning prior to mobilizing to the FTA.

It was the intent of the field personnel to purge all wells using pump #1 prior to sampling. During purging of the first well (MW-201), pump #1 froze due to low ambient air temperatures. Pump #1 was removed from the well and placed in a vehicle to thaw. At this time, the backup pump (pump #2) was lowered into the second well (MW-202). MW-202 was purged with pump #2 and subsequently sampled. By the time sampling was completed in MW-202 pump #1 had thawed and was again functioning. Pump #1 was used to complete the purging of MW-201 and the remaining 200-series wells sampled during the supplemental investigation. Pump #2 was

used to purge only MW-202. These events were witnessed by Jamie Asher of New York State Department of Environmental Conservation (Region I).

The probable method by which methyl hydrate was introduced in the groundwater in MW-202 was through reversal of the switch controlling the pumping mechanism of pump #2 prior to purging. The switch mechanism on the submersible pumps must be turned through the reverse mode prior to reaching the forward mode. If the switch was turned quickly, no backwash can occur; however, a momentary pause in the reverse mode would result in discharging the contents of the pump and hose into the well.

The most likely method by which methyl hydrate was introduced in the casing water within MW-202 was through reversal of the pumping mechanism as described above. Pump #2 was lowered into the well and turned on at the water table. The pump was continually lowered (while running) to the screened interval and run until the appropriate volume had been discharged from the well. Following purging, a groundwater sample was collected from well MW-202 with a bottom loading bailer. It is ABB-ES' belief that the residual methyl hydrate in the pump and hose was discharged to the well upon pump start-up and, due to the extremely high recharge rate of the well, nearly all the groundwater that was removed would have come through the screened section of the well--not the top of the water column where the 2-butanone was introduced. The result would be a column of water above the well screen containing 2-butanone that was never fully removed during purging. Hence, a sample taken with a bottom loading bailer from MW-202 would result in a mix of contaminated upper level casing water containing 2-butanone and lower formation water.

It needs to be pointed out that methyl hydrate was not used during the installation of 200-series monitoring wells or soil borings and that 2-butanone, ethanol, and ethyl acetate were not detected in other 200-series well (MW-201 through MW-204, installed during the supplemental investigation) sampled following purging with pump # 1.

In summary, insufficient rinsing (with deionized water) and removal of methyl hydrate in the submersible pumps during groundwater sampling rounds 1 through 3, and the probable reversal of the pumping mechanism in pump #2 while purging well MW-202, resulted in 2-butanone being introduced to the well casing water at several well locations at the FTA. ABB-ES' field sampling personnel associated with this field effort have signed an affidavit verifying these statements (Attachment J).

Comment: In Paragraph 1 Page 3 the reviewer contends that the February 1989 distributions of 2-butanone, ethanol, and ethyl acetate can be interpreted as describing a contaminant plume extending past the downgradient edge of the site and centered on Well 107B.

Response: As previously noted, it is the conclusion of ABB-ES that there is no contaminant plume. The maximum amount of methyl hydrate discharged to the surface was 20 gallons over three rounds (rounds 1, 2, 3) of groundwater sampling (from April 1987 to July 1989). All (5 gallons) of the isopropanol (as well as the deionized water) used for equipment cleaning procedures during initial site characterization activities was containerized in a 55-gallon drum that was later sampled for TCLP analytes and disposed of by the base civil engineer. What the reviewer is interpreting to be a contaminant plume is actually the distribution of 2-butanone within the stagnant water column in several well casings.

Comment: In Paragraph 2 Page 3, the reviewer contends that the purging-and rinsing experiment conducted at Well 107B in October 1991 does not eliminate the possibility of a contaminant plume extending past the down gradient edge of the site and centered on Well 107B. The basis for the reviewer's contention is that by the time the October 1991 experiment was conducted, four and a half years had elapsed since the first and major on-site use of methyl hydrate, and that at this time, only the dilute, trailing edge of a contaminant plume would have been detectable at Well 107B. The reviewer further contends that extensive purging may have primarily drawn cleaner, upgradient groundwater into the well, bringing 2-butanone levels down to below detection limits.

Response: It must be pointed out that the boundaries of contaminant plumes are not as crisply defined as suggested by the reviewer. It is highly improbable that 2-butanone concentrations would range from 1600 parts per billion (concentration in MW-107B at the beginning of round 5 groundwater sampling) to non-detect within a few feet of the well (approximate area of groundwater removed during round 5 purging test).

Furthermore, the statement made by the reviewer suggesting that cleaner upgradient water was drawn into well MW-107B prior to sampling is virtually impossible. A theoretical drawdown of less than 0.04 feet was calculated using GWFLOW and PT1 (pumping test design models) for well MW-107B, assuming an average hydraulic conductivity of 99 ft/day (as reported in the *Site Characterization Report*), an aquifer thickness of 65 feet (conservative estimate to increase effects of pumping), a discharge rate of 1 gallon/minute (pumping rate of submersible pump used to purge well) and a pumping time of approximately 3 hours (08:43 to 11:45 on 02 Dec 91 for pumping and sampling--actual pumping time was less). This demonstrates that pumping at 1 gallon/minute had virtually no effect on the hydraulic gradient, which is the driving component of groundwater flow. In other words, the zone of influence created during pumping was minimal, and would not result in clean upgradient groundwater being drawn into the well to the exclusion of the speculative contaminated down gradient groundwater. The area encompassing the 2-butanone concentration gradient (1,600 ppb to non-detectable concentrations) will be much greater than the area of groundwater removed by pump purging.

In addition, a well that is 1.5 feet in diameter (MW-107B is 2-inches in diameter) with approximately 65 feet of water in the casing (approximate height of water in MW-107B) would contain approximately 180 gallons of water, which is equal to the volume of water which ABB-ES' records show was purged from MW-107B. This indicates that the volume of water removed from MW-107B came from the area immediately proximate to the well.

Finally, stagnation point/capture zone calculations indicate that the stagnation point (point at which pumping has no influence on direction of groundwater flow) downgradient of the well is approximately 6.5 feet. The zone of capture (point at which groundwater begins to be influenced by pumping well) on the upgradient side of the well is approximately 13 feet. However, this does not mean that water 13 feet upgradient from the well was drawn into the well. The area defined by the zone of capture is much greater than the volume of water actually removed during the purging experiment. In order to withdraw water from 13 feet upgradient from the well, the duration of pumping would have to be extended so that the volume of water, as defined by the capture zone, is removed. The zone of capture created during the well purging experiment indicates that there was minimal influence on the lateral movement of groundwater.

In conclusion, the hydraulic conductivity ($> 3.5 \times 10^{-2}$ cm/sec) of the Upper Glacial Aquifer is so high that pumping at a rate of 1 gallon per minute (discharge rate of Keck submersible pump used on site) would have virtually no measurable effect on the lateral migration of groundwater or possible contaminants therein. It is our belief that no contaminant plume exists. The measured decrease in contaminant concentration from 1600 parts per billion to non-detect throughout the purging experiment conducted during round 5 groundwater sampling is the result of effectively removing all residual contamination from the stagnant well casing water. Drawdown, well volume and stagnation point calculations supporting statements presented above are provided in Attachment K.

Comment: In Paragraph 3 of Page 3 the reviewer contends that the description given of the field experiment is incomplete in that it failed to report pH, temperature and specific conductance field test results, or quantify the water exchange rate and number of well volumes drawn and recharged during the 10 minutes of well rinsing.

Response: Regarding the incomplete description given for the field experiment in the *Evaluation of 2-Butanone in Groundwater Samples* report, temperature, pH and specific conductance were measured during collection of each groundwater sample as shown in field notes provided in Attachment L. These data are collected as a standard procedure when sampling groundwater. The purpose of collecting these data are to indicate the point (when sampling) at which formation water (not casing water) is being sampled. Standard practice is that purging should be discontinued when temperature, pH and specific conductance stabilize within 10 percent of the

previous measurement. As discussed in Item 28 of the chronology, the purpose of the purging experiment during round 5 groundwater sampling was not to collect formation water, but to demonstrate that the contaminants present in the well were attributed to contaminated stagnant well casing water. These data (temperature, pH and specific conductance) were reviewed, but not perceived as being necessary to support conclusions presented in the *Evaluation of 2-Butanone in Groundwater Samples* report because they were irrelevant with respect to the experiment objectives. Having removed 10 well volumes there would be no question that all well casing had been removed and that only groundwater was now being purged (and sampled).

In response to the second part of the reviewer's comment, a pumping (exchange) rate of 1 gallon per minute was maintained throughout the purging and recirculating experiment on all wells (see Attachment L). The pumping time (MW-107B) lasted approximately 3 hours (08:43 to 11:45 on 02 Dec 91 for pumping and sampling--actually pumping time was less due to periodic well sampling), which is equivalent to 180 gallons of water removed.

In response to the reviewer's comment regarding the volume of water drawn from and recharged to the well, a pumping rate of 1 gallon per minute yields 10 gallons recirculated over a 10 minute period. The reviewer should keep in mind that the well did not undergo a net loss or gain of water during the 10 minutes of recirculating. The purpose of recirculating the casing water was to rinse the portion of the casing above the water table (to remove residual 2-butanone deposited during fluctuations in the water table), and to agitate the water column to eliminate potential stratification of the 2-butanone and permit more effective removal through purging. By agitating the water column, samples more representative of the contents of the well casing could be collected.

Comment: In Paragraph 3 of Page 3 the reviewer points out that it is not clear that the experimental procedure could have been conducted without "air stripping" the rinse water.

Response: It is unlikely that "air stripping" would occur during rinsing as suggested by the reviewer. Although 2-butanone, ethanol, and ethyl acetate are volatile compounds (low molecular weight and high vapor pressures), they are not readily purged from water. These compounds possess extremely low Henry's Law constants. Henry's Law describes the partitioning of solutes between air and water. The volatility of a compound can be ascertained through evaluation of the Henry's Law constants; the greater the constant, the more susceptible the compound is to volatilization. The Henry's Law constants for 2-butanone, ethanol, and ethyl acetate are $2.74\text{E-}05$, $4.48\text{E-}05$, and $1.2\text{E-}04$, respectively. In contrast, highly volatile compounds such as tetrachloroethene, trichloroethene and benzene have Henry's Law constants of $2.59\text{E-}02$, $9.11\text{E-}03$ and $5.58\text{E-}03$, respectively. The Henry's Law constants of the contaminants of concern suggest that "air stripping" of these compounds during rinsing of the

well was minimal. Even if air stripping did occur, it would not have affected the final results because the final step involved extensive (seven volume) purging of the rinse water. Standard protocol prior to sampling a well is to purge a minimum of three well volumes. Purging an additional seven volumes following the recirculation experiment insured that only formation water was collected during sampling (see response to following comment for additional explanation).

Comment: In Paragraph 3 of Page 3 the reviewer further contends it is not clear that the additional seven volumes purged following the well-rinsing exercise was sufficient to bring only "unexchanged" groundwater back into the well for sampling because the volume of rinse water recharged into the well is unspecified. As a result the reviewer contends that it is thus possible that artificially low concentrations of VOCs were measured.

Response: As stated previously, no new water was added to the well while recirculating. The well did not undergo a net loss or gain of water during the 10 minutes of recirculating. Therefore, purging seven volumes following the recirculating procedure was more than sufficient to withdraw "unexchanged" water from the formation such that samples exhibiting representative concentrations of VOCs could be collected.

Comment: In Paragraph 4 of Page 3 the reviewer contends that the report introduces, but fails to fully develop, information regarding heretofore unsuspected extremely high levels of ethanol contamination in groundwater. Additional analysis performed as part of this report revealed that the GC relative response factor for ethanol is very low, averaging 0.00148. In the groundwater analyses performed, however, ethanol was detected and reported as a tentatively identified compound, and its concentrations estimated assuming a relative response factor of 1. The reviewer therefore contends that actual concentrations of ethanol in groundwater must have been two to three orders of magnitude higher than the reported estimated concentrations. The highest estimated ethanol concentration reported was 33,000 ppb; the reviewer therefore concludes that the highest actual concentration may have been as much as 33,000 ppm, or 3.3%.

Response: Relative to the response factor of the gas chromatograph and the implications that *actual* concentrations could be two to three orders of magnitude higher (fourth paragraph on Page 3 of reviewer's comments), ABB-ES deliberately avoided making calculations such as the one made by the reviewer because of the variabilities involved with TIC analysis. Instead, ABB-ES used generalities such as "two or three orders of magnitude" to describe the low bias of ethanol concentrations. But to follow through more specifically on the reviewer's logic, the "actual" concentration of ethanol in the mentioned sample can be estimated by dividing the reported TIC concentration by the response factor ($33,000 \mu\text{g/L}$ [highest estimated concentration] \div 0.00148 [GC response factor] = $22,000,000 \mu\text{g/L}$, or 2.2%). The presence of ethanol at this

concentration is reasonable because ethanol constitutes 90% of methyl hydrate and ethanol is miscible in water (i.e. all of the ethanol would have dissolved into groundwater).

Furthermore, the ratio of ethanol concentration to the *known* concentration of 2-butanone can be estimated accordingly: $2.2\text{E}+07 \mu\text{g/L}$ (concentration of ethanol corrected for GC response factor) $\div 53,000 \mu\text{g/L}$ (maximum concentration of 2-butanone in sample) or 415:1. The data presented in Section 3.1 of the report (*Evaluation of 2-Butanone in Groundwater Samples*) indicates the ratio of ethanol to 2-butanone in industrial grade methyl hydrate is approximately 90% to 2.5% or 36:1. Considering that: 1) the response factor for ethanol was determined at a different lab than the sample analyses; 2) 2-butanone has a higher Henry's Law constant than ethanol, and 3) 2-butanone is more susceptible to biodegradation than ethanol, the order of magnitude difference between the two ratios is reasonable. Regardless of the similarity or dissimilarity of these two ratios, it is ABB-ES' belief that the variabilities involved preclude precise numerical computation and comparison of 2-butanone and ethanol concentrations in the manner attempted by the reviewer.

Comment: In Paragraph 5 of Page 3 the reviewer indicates that the State is unable to accept the theory that 2-butanone, ethyl acetate and ethanol detections in groundwater samples taken between April 1987 and October 1991 are mere artifacts and contends that these compounds may be "genuine aquifer contaminants". Further the reviewer assumes that one or more groundwater contaminant plumes were created following use of methyl hydrate at the site, which may have migrated past the farthest-downgradient monitoring point extant at the site.

Response: There are several flaws in the conclusion of the State with regard to developing the hydrochemical conceptual model presented in this comment. First, methyl hydrate was never used as a decontamination solvent during drilling and soil sampling activities--only during groundwater sampling activities. Secondly, only 5 gallons (not 85 gallons) of isopropanol were used for equipment decontamination during drilling and soil sampling activities, and thirdly, the only solvent poured on the ground throughout the entire site characterization consisted of approximately 20 gallons of methyl hydrate (containing only 2-3% by volume of 2-butanone, or 0.6 gallons) that were used during the total groundwater sampling activities over the two year investigation period when methyl hydrate was used as a decontamination fluid. As previously stated, the locations of these discharges are dispersed across the facility as illustrated in Figure 1. At each location in which a submersible pump was used to purge the well, approximately one to two liters of methyl hydrate was potentially discharged to the ground. This type of minimal discharge and dispersion would not originate a "groundwater plume". ABB-ES' field sampling personnel associated with this field effort have signed an affidavit verifying these statements (Attachment J).

Comment: In Paragraph 1 of Page 4 the reviewer indicates that under 10 NYCRR Part 5, Sub-Part 5-1, 2-butanone, ethyl acetate and ethanol are Unspecified Organic Contaminants, each subject to an MCL of 50 ppb and a combined total MCL of 100 ppb in public drinking water supplies. Further the reviewer indicates that the SCWA wellfield, located 4,000 feet downgradient of the Fireman's Training Area site, may be susceptible to eventual contamination in excess of the MCLs which could necessitate closure of the wellfield, or, in the alternative, wellhead treatment to remove the contamination.

Response: As shown below in the response to comment #4 of "Matters To Be Addressed", a solute transport analysis was conducted to estimate the maximum concentration of a plume at the well field that originated from a point source (well MW-107B) assuming the mass of contaminants was a slug (worse case) equivalent to 85 gallons of undiluted methyl hydrate that was discharged directly to the aquifer (not the ground surface). The model results indicate that concentrations would be less than the MCL of 50 parts per billion with a source of 85 gallons of methyl hydrate, and at a non-detectable concentration given the actual volume (20 gallons) of methyl hydrate discharged to the ground.

MATTERS TO BE ADDRESSED

General Comment: "While the report at hand does not constitute a full report of the supplemental site investigation, we expect that the full report is forthcoming, and will address the issues raised in these comments and include the following:"

Response: The *Final Site Characterization Report* and the *Evaluation of 2-Butanone in Groundwater Samples* report have been issued. The findings and recommendations presented in these reports are still valid and appropriate. No other reports, other than a Decision Document, are to be provided for this site.

Comment 1) To fully describe the use of methyl hydrate at the site, all field investigation documentation should be reviewed to discover the actual amount of methyl hydrate used on-site, the locations of the on-site decontamination stations during each field investigation, any reports of accidental spills of decontamination fluid, and the manner in which any left-over methyl hydrate was disposed.

Response: ABB-ES reviewed available documentation and questioned field personnel and determined that: 1) 20 gallons was the maximum amount of methyl hydrate that could have been used on the site, 2) decontamination stations were near each well or boring being drilled (See Figure 1), 3) all decontamination fluids generated during the initial drilling and soil sampling

activities were containerized in a 55-gallon drum as shown by the attached photo taken at well MW-107B, 4) there are no known or recorded incidents of solvent spills during the drilling and soil sampling activities, 5) the methyl hydrate used by the groundwater sampling technicians for equipment decontamination (approximately 20 gallons maximum) was disposed of on the ground (along with deionized water and Liquinox) following its use, and 6) isopropanol, the decontamination liquid used during the initial drilling and soil sampling activities was containerized and disposed of by the Base Civil Engineer (Captain Jesus Figueroa). ABB-ES' field sampling personnel associated with this field effort have signed an affidavit verifying these statements (Attachments I and J).

Comment 2) Detections of 2-butanone in soil samples JSS011 (3/20/87, 3.5-4.0 feet, 5.6 ppm) and JTB004 (3/22/87, 15 feet, 8.6 ppm) should be reconsidered a potentially indicative of spillage locations or disposal points for decontamination fluid and/or decontamination wash water.

Response: The units reported by the reviewer in this comment are incorrect. The concentrations of 2-butanone in soil samples JSS011 and JTB00415, collected in March 1987, were 5.6 and 8.6 $\mu\text{g/kg}$ (*ppb*), not ppm (*Final Site Characterization Report*). Examination of the TIC data for these samples did not reveal the presence of ethanol, ethyl acetate, or any other of the characteristic TICs noted in methyl hydrate. The concentrations reported in these samples are low and do not pose an environmental or health threat (*Final Site Characterization Report*).

Detection of 2-butanone in these soil samples can not be related to the use of methyl hydrate for equipment decontamination because they were collected prior to the first round of groundwater sampling, which was the first time methyl hydrate was used on-site. For soil sampling, isopropanol was used as a decontamination fluid. In addition, all decontamination liquids used during the soil boring and monitoring well installations were containerized by ABB-ES field sampling personnel. 2-Butanone is reported to have been used as a flammable liquid for fire training exercises at the FTA prior to 1971 (*Final Site Characterization Report*). Residual 2-butanone contamination identified in the surface and subsurface soil samples collected in March 1987 is likely the result of former FTA activities.

Comment 3) It is important to evaluate vertical as well as horizontal components of groundwater flow direction under the site, as these may disclose preferential flow pathways, providing a clearer explanation for the distribution of contaminant detections at the various monitoring points through time. We note that water level measurements taken in 1987 suggested a persisting downward component of flow at upgradient well cluster MW107A, B and persisting downward and upward component of flow toward 107B at downgradient well cluster MW107A,

B, C. These, as well as February and December 1989 water level data, should be evaluated to delineate groundwater flow pathways beneath the site as clearly as possible.

Response: The high concentration of 2-butanone in MW-107B is likely attributed to monitoring well design rather than aquifer contamination and preferential contaminant migration. Well MW-107A is a deep well relative to MW-107B; therefore, more casing water (above the screened interval) is available for dilution of introduced 2-butanone. Assuming the volume of methyl hydrate discharged into both wells was the same, 2-butanone concentration would be greater (which it is) in the shallow well (MW-107B).

Comment 4) The report should include a solute transport analysis which evaluates the anticipated concentrations of 2-butanone, ethyl acetate and ethanol at several specified locations and times, including the SCWA wellfield (along the lines of the generic dilution factor and transit time calculations included in the June 1989 Site Characterization Report) under a "no action" scenario. Should the results of such analysis indicate potential for MCLs to be exceeded at the wellfield, a need for additional downgradient monitoring will be indicated, and a full feasibility study to evaluate remedial alternatives must be completed.

Response: A solute transport analysis was conducted in response to the reviewer's comment. The PLUME3D module of the SOLUTE groundwater modeling software (IGWMC, ver. 2.00, 1989) was used to estimate the maximum concentration of a plume from a point source in three-dimensional regional flow. Calculations and model output are included in Attachment M.

A worst-case scenario was modeled in which a contaminant slug (2-butanone) was instantaneously introduced into the aquifer assuming no contaminant retardation (i.e., contaminant flows at the same rate of groundwater). At the concentration of 2-butanone detected in well MW-107B (56 mg/L), the mass of 2-butanone would be equivalent to 0.005 pounds of 2-butanone. With this mass input, no detectable ($< 0.1 \mu\text{g/L}$) concentrations would be observed at the Suffolk County well field, approximately 4,000 feet downgradient of the FTA.

A second scenario was modeled in which the slug of 2-butanone was increased to 4.02 pounds (equivalent to 20 gallons of methyl hydrate at 3 percent 2-butanone by volume i.e., maximum quantity possible). Assuming the 2-butanone was instantaneously discharged to the aquifer, and there was no contaminant retardation, the maximum concentration at the well field was estimated at $19 \mu\text{g/L}$, which is below the MCL of $50 \mu\text{g/L}$ for Unspecified Organic Contaminants under 10 NYCRR Part 5, Sub-part 5-1. The distance at which the concentration would fall below instrument detection limits (approximately 0.005 mg/L) was estimated at 9,500 feet downgradient from the source. However, it is more probable that the concentration of

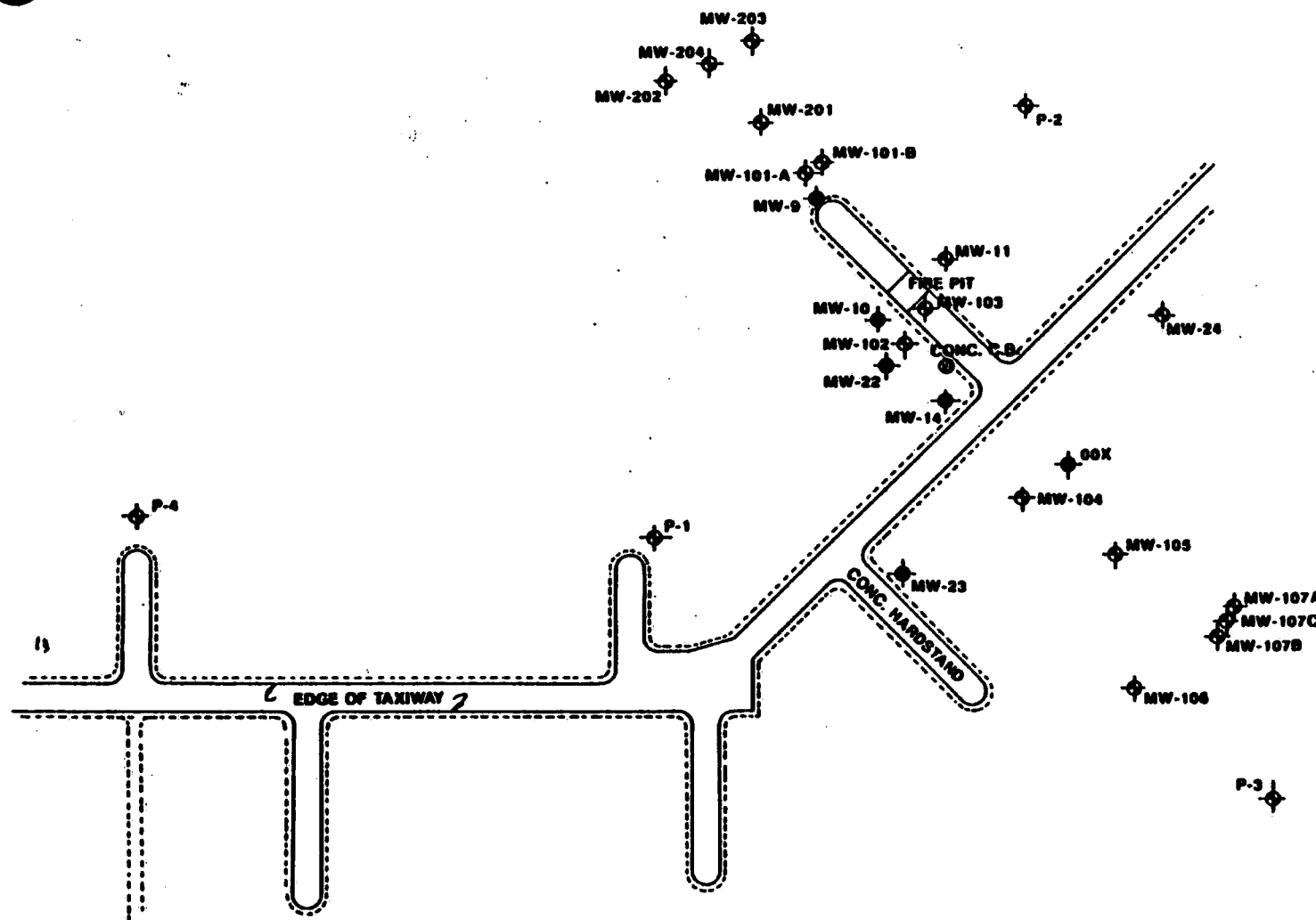
2-butanone would be non-detect at the well field given the effects of adsorption through the flow pathway and additional dilution available at the well head.

A third scenario was modeled that considered attenuation of the contaminant through the vadose zone using the *Jury* model, as presented in Water Resources Research, Volume 26, No. 1 pp. 13-20, 1990 (Attachment N). The analytical model considers the net infiltration rate through the soil, the volatilization potential of the contaminant, and partitioning to soil as well as the thickness of the unsaturated zone. The model was run assuming that 4.02 pounds of 2-butanone (equivalent to 20 gallons of methyl hydrate) was discharged to the ground surface in an area approximately 9 square feet (3' x 3'). Assuming that based on site conditions the soil has a 30 percent porosity, 20 gallons of methyl hydrate would saturate this area to a depth of one foot. The initial concentration of 2-butanone in this volume is calculated at 3850 ppm. The model indicates that the maximum concentration of 2-butanone that would reach the water table is 126 mg/l. The model shows that 2-butanone would discharge to the water table over a period of 160 days. Subsequent calculations indicated that approximately 17.2 grams of 2-butanone would discharge to the water table over the entire 160 days. This mass represents only about one percent of the original mass of 2-butanone that was discharged to the ground. Most of the contaminant loss (84 percent) was attributable to volatilization. The remaining portion (15 percent) was adsorbed to the unsaturated soil and biodegraded. To model the migration of the 2-butanone once it reached the water table, a worst case was assumed whereby the entire 17.2 grams of 2-butanone was introduced into the aquifer as a slug. The scenario was modeled using the PLUME3D module of the SOLUTE groundwater modeling software (IGWMC, ver. 2.00, 1989). The model indicates that the concentration of 2-butanone would be below detectable limits (i.e., <0.005 mg/L) at a downgradient distance of less than 475 feet. This distance would actually be significantly less because the mass of 2-butanone (17.2 grams) that discharged to the water table did so over a 160 day period.

A fourth and final scenario was modeled in which the mass of 2-butanone was increased to 17.1 pounds (equivalent to 85 gallons of methyl hydrate at 3 percent 2-butanone by volume). Assuming 2-butanone was instantaneously discharged to the aquifer, and there was no contaminant retardation, the maximum concentration at the well field would be estimated at 81 µg/L, which is slightly greater than the MCL of 50 µg/L for Unspecified Organic Contaminants as specified under 10 NYCRR Part 5, Sub-part 5-1. If 85 gallons of methyl hydrate were to be poured on the ground, volatilization and adsorption throughout the vadose zone would result in only a fraction of the 2-butanone actually reaching the water table. Retardation in the aquifer would further diminish the concentration of 2-butanone along the groundwater flow pathway. It is highly probable that the concentration of 2-butanone would be significantly below the MCL at the well head under this scenario.

Conclusion

The *Evaluation of 2-Butanone in Groundwater Samples* report demonstrates that the presence of 2-butanone in groundwater samples collected from several of monitoring wells during past sampling events is attributable to the use and insufficient rinsing of a small volume of commercial-grade methyl hydrate which was used as a decontamination fluid for groundwater sampling equipment. The methyl hydrate was used in accordance with work plans prepared for site activities and reviewed by appropriate agency personnel prior to implementation. It is our belief that additional numerical modeling is unnecessary given the nature and distribution of site-related groundwater contaminants at the FTA. The groundwater plume modeling results presented above further support our recommendation to proceed with a Decision Document at the FTA.



LEGEND

- ◆ EXISTING WELLS
- ◆ WELLS INSTALLED BY E.C. JORDAN CO. FROM MARCH TO APRIL 1987
- ➔ DIRECTION OF INTERPRETED GROUNDWATER FLOW

FIGURE 1
MONITORING WELL LOCATION MAP
FIRE TRAINING AREA
SUFFOLK COUNTY AIRPORT
WESTHAMPTON BEACH, NEW YORK

ATTACHMENT C



STATE OF NEW YORK
DEPARTMENT OF LAW
120 BROADWAY
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(212) 416-8481

November 5, 1992

Mr. Sean Walter
106th Rescue Group/EMO
Environmental Management
Suffolk County ANG Base
Westhampton Beach, NY 11978-1294

RE: "Evaluation of 2-Butanone in Groundwater Samples"
Suffolk County Air National Guard Base
Suffolk County Airport
Westhampton Beach, New York
March 1992

Dear Mr. Walter:

We have reviewed the above-referenced report and offer the following comments:

This report provides data and analysis in persuasive support of the theory that the use of methyl hydrate as a decontamination fluid during field investigations conducted at the Firemen's Training Area is the source of 2-butanone detected in groundwater samples during these investigations. The report correlates detections of 2-butanone at various concentrations in various site monitoring wells since April 1987 with concurrent detections of ethanol and ethyl acetate. These three compounds are shown to be constituents of methyl hydrate, and their relative concentrations in groundwater samples are shown to be consistent with their relative concentrations in methyl hydrate. This work provides a new basis for evaluating the history of these detections at the site. Some of the report's arguments and conclusions, however, are either contradicted or inadequately supported by available information.

For example, the report suggests only that residual methyl hydrate, trapped in decontaminated submersible pumps used to purge the wells prior to sampling, is "one possible method for the introduction of methyl hydrate into groundwater samples". There is another, equally possible pathway to groundwater that requires recognition in the reevaluation of 2-butanone detections at the site. That pathway is described in both work plans prepared for the site: "...water generated during drilling and decontamination activities will be poured on the ground and allowed to percolate into the soils where it originates." Given this field procedure, it must be assumed that a ready pathway to groundwater existed for all the methyl hydrate used at the site, and not just for "trapped residuals" in pumps.

The work plans also provide a basis for approximating the mass of contaminant introduced to the groundwater during each of the field investigations. The work plan for the April-June 1987 investigation called for the on-site use of 85 gallons of decontamination fluid. The work plan for the February 1989 supplemental investigation called for 6 gallons of decontamination fluid. These plans therefore provide an indication that the mass of contaminant involved was limited, and that the main mass of contamination was probably introduced in the spring of 1987, providing a starting point for fate and transport analysis.

Given the nature of the likely pathways, the estimated groundwater flow rate at the site of 300 feet per year, and the limited mass of contaminant involved, it is not surprising that the groundwater sampling data did not disclose a single, simple, easily definable contaminant plume. However, conclusions drawn in the report that 2-butanone is not a "genuine aquifer contaminant" are not adequately supported in several regards.

While the report notes simply that 2-butanone concentrations declined following discontinuation of methyl hydrate use at the site, we note that all three evaluated constituents of methyl hydrate (2-butanone, ethanol and ethyl acetate) continued to be detected at high levels in downgradient Well 107B, for the entire period between April 1987 and October 1991. Ethanol and ethyl acetate concentrations actually increased at Well 107B between sampling rounds 4 and 5, even though methyl hydrate was not used for either of these two sampling rounds. These observations are not inconsistent with what could be attributed to contaminant plume migration toward and past this downgradient monitoring point. They are also inadequately explained by the "trapped residuals" theory. Similarly, the observed declines in contaminant concentrations at more up-gradient wells after round 3 may simply reflect the migration of dissolved contamination past the available monitoring points.

Furthermore, ethanol was detected in Well 202 in December 1989, despite the fact that this well was installed and sampled eight months after the last on-site use of methyl hydrate. The ethanol detected in the sample from Well 202 therefore could not have resulted from "trapped residuals", but rather must indicate ethanol contamination in the groundwater. Finally, the February 1989 distributions of 2-butanone, ethanol, and ethyl acetate can be interpreted as describing a contaminant plume extending past the downgradient edge of the site and centered on Well 107B.

Even the purging-and-rinsing experiment conducted at Well 107B in October 1991 fails to eliminate this possibility. Since, by the time the October 1991 experiment was conducted, four and a half years had elapsed since the first and major on-site use of methyl hydrate, it is possible that only the dilute, trailing edge of a contaminant plume would have been detectable at 107B by this time. The extensive purging may have primarily drawn cleaner, upgradient groundwater into the well, bringing contaminant levels down to below detection limits.

The description given of this field experiment is incomplete in that it fails to report pH, temperature and specific conductance field test results, nor does it quantify the water exchange rate and number of well volumes drawn and recharged during the 10 minutes of well rinsing. It is not clear that this procedure could have been conducted without "air stripping" the rinse water. Furthermore, because the volume of rinse water recharged into the well is unspecified, it is not clear that the additional seven well volumes purged following the well-rinsing exercise was sufficient to bring only "unexchanged" groundwater back into the well for sampling. It is thus possible that artificially low concentrations of VOCs were measured.

The report also introduces, but fails to fully develop, information regarding heretofore unsuspected extremely high levels of ethanol contamination in groundwater. Additional analysis performed as part of this report revealed that the GC relative response factor for ethanol is very low, averaging 0.00148. In the groundwater analyses performed, however, ethanol was detected and reported as a tentatively identified compound, and its concentrations estimated assuming a relative response factor of 1. Actual concentrations of ethanol in groundwater must therefore have been two to three orders of magnitude higher than the reported estimated concentrations. The highest estimated ethanol concentration reported was 33,000 ppb; the highest actual concentration may therefore have been as much as 33,000 ppm, or 3.3%.

Given these observations, the State is unable to accept the theory that 2-butanone, ethyl acetate and ethanol detections in groundwater samples taken between April 1987 and October 1991 are mere artifacts and that these compounds are not "genuine aquifer

contaminants". Rather, the assumption must be that one or more groundwater contaminant plumes were created following use of methyl hydrate at the site, and may now have migrated past the farthest-downgradient monitoring point extant at the site.

Under 10 NYCRR Part 5, Sub-Part 5-1, 2-butanone, ethyl acetate and ethanol are Unspecified Organic Contaminants, each subject to an MCL of 50 ppb and a combined total MCL of 100 ppb in public drinking water supplies. The SCWA wellfield located 4000 feet downgradient of the Firemen's Training Area site may be susceptible to eventual contamination in excess of the MCLs. Should this occur, it could necessitate closure of the wellfield, or, in the alternative, wellhead treatment to remove the contamination.

MATTERS TO BE ADDRESSED

While the report at hand does not constitute a full report of the supplemental site investigation, we expect that the full report is forthcoming, and will address the issues raised in these comments and include the following:

1) To fully describe the use of methyl hydrate at the site, all field investigation documentation should be reviewed to discover the actual amount of methyl hydrate used on-site, the locations of the on-site decontamination stations during each field investigation, any reports of accidental spills of decontamination fluid, and the manner in which any left-over methyl hydrate was disposed.

2) Detections of 2-butanone in soil samples JSS011 (3/20/87, 3.5-4.0 feet, 5.6 ppm) and JTB004 (3/22/87, 15 feet, 8.6 ppm) should be reconsidered as potentially indicative of spillage locations or disposal points for decontamination fluid and/or decontamination wash water.

3) It is important to evaluate vertical as well as horizontal components of groundwater flow direction under the site, as these may disclose preferential flow pathways, providing a clearer explanation for the distribution of contaminant detections at the various monitoring points through time. We note that water level measurements taken in 1987 suggested a persisting downward component of flow at upgradient well cluster MW107A,B and a persisting downward and upward component of flow toward 107B at downgradient well cluster MW107A,B,C. These as well as February and December 1989 water level data should be evaluated to delineate groundwater flow pathways beneath the site as clearly as possible.

4) The report should include a solute transport analysis which evaluates the anticipated concentrations of 2-butanone,

Sincerely,

Patricia Hime

cc: Nancy Stearns, Norman Spiegel, NYSDOL
Anthony Candela, NYSDC Region 1
Earl Barcomb, NYSDC Hdqtrs
Steven Cary, SCDHS

ATTACHMENT D

AFFIDAVIT

I, the undersigned Robert M. Burger, do state as follows:

1. This affidavit documents my recollection of the grant of a verbal authorization for changing decontamination fluid use from isopropanol to methyl hydrate at Suffolk County Air National Guard Base. This statement is based on my personal recollection of the events during the time periods described below.

2. I was manager of the Monitoring Department in 1987 at E.C. Jordan and was involved in the selection and implementation of sampling decontamination procedures.

3. Prior to March 1987, E.C. Jordan Co. routinely used a variety of decontamination fluids including hexane, freon, and methanol. A review of the health and safety constraints involved with the use of each of these fluids indicated that a less potentially harmful fluid was desired. A search and technical review was performed and Isopropanol was selected and utilized for decontamination up to March 1987.

4. During the period between February 1987 and March 1987, information from field staff relative to the performance of isopropanol as a decontamination fluid was brought to mine and other staff's attention. During cold weather, isopropanol was found to not dissipate readily during the equipment rinse and decontamination phase. A search was conducted to find an alternative fluid to replace isopropanol. Methyl hydrate was considered to be an acceptable replacement from a technical standpoint.

5. E.C. Jordan advised the HAZWRAP project manager of the proposed change and no objections were noted.

Signed under the pains and penalties of perjury this 14 day of April, 1993.



Witness



Robert M. Burger

Dated: 4/14/93

Dated: 4/14/93

ATTACHMENT E

AFFIDAVIT

I, the undersigned Charles P. Lyons, do state as follows:

1. This Affidavit documents my recollection of the grant of a verbal waiver from HAZWRAP protocols to suspend the use of a decontamination solvent at Suffolk County Air National Guard Base. I have personal knowledge of the facts contained herein.

2. During cost negotiations on February 7, 1991 (approximate date), at HAZWRAP's offices in Oak Ridge, Tennessee, questions regarding throughput of field gas chromatographs were questioned and HAZWRAP's Quality Assurance Director, Richard Westmoreland's attendance was requested in the meeting. After the questions at hand were settled, Richard Hebert, E.C. Jordan Project Manager (Jordan), requested that Jordan be given permission to waive the use of decontamination solvents for this event.

3. Richard Westmoreland asked specific questions about the request. Richard Hebert explained that Jordan was currently conducting studies to determine the contents of its methyl hydrate. Dwight Robertson, HAZWRAP Project Manager, explained that Jordan suspected 2-Butanone contamination in the methyl hydrate and that it was asking for the variance since it was the suspected source of contamination at Suffolk.

4. Richard Westmoreland authorized Jordan to suspend use of a decontamination solvent for this particular field event only. He stated that if Jordan suspected contamination in the solvent, Jordan should select a new solvent soon, as other projects were on-going and they would be required to use a solvent. Richard Westmoreland said that they use of Liquinox and water was permissible as the only decontamination fluids for this event only.

5. To the best of my recollection, this was never documented, but Jordan was requested to make sure that methyl hydrate was not listed as an expendable fluid on the appropriate table in the proposal.

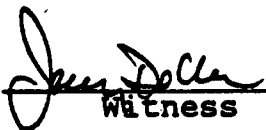
6. Therefore, when the groundwater sampling event occurred, no methyl hydrate was mobilized to the site. To eliminate cross contamination from another site, ABB-ES decontaminated the submersible pump selected for purging the monitoring wells. This was accomplished by David Dionne (ABB-ES) and me in ABB-ES's staging area by pumping copious amounts of tap water through the pump.

7. When groundwater sampling commenced for Round 4 on December 12, 1991, the first well to be sampled was MW-201. The decontaminated pump was lowered into the well to begin purging. During the process of purging, the pump tubing outside of the well froze (the ambient air temperature was approximately 30° F).

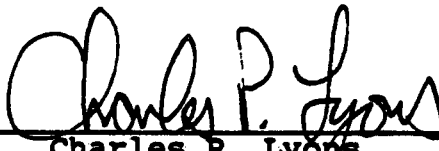
ABB-ES then removed this pump (pump #1) to place it into one of the vehicles to thaw out. A second pump (pump #2) that was brought on-site only as a backup pump (pump #2 was not decontaminated with copious amounts of tap water like pump #1 and had last been decontaminated at a site using methyl hydrate as the decontamination solvent) was then used to purge MW-202. When MW-202 had been purged, it was sampled and MW-201 was then purged using pump #1 which had now thawed out. All remaining wells sampled on-site during Round 4 were purged utilizing pump #1.

8. The pumps that were mobilized to the site are of a design such that the knob to turn the pump on (as to pump water out of the well) must be turned from the off position past the reverse position (as to pump water out of the pump into the well) to get to the on position. Also these pumps do not have ball check foot valves that prevent fluids inside the pump from draining back through the pump into the well (otherwise the pump could not be operated in the reverse mode).

Signed under the pains and penalties of perjury this 14 day of April, 1993.



Witness



Charles P. Lyons

ATTACHMENT F

SITE INVESTIGATION ACTIVITIES
AND PROJECT COMMUNITY RELATIONS

SUFFOLK COUNTY AIR NATIONAL GUARD BASE
WESTHAMPTON BEACH, NEW YORK

PROPOSAL FOR THE STATEMENT OF WORK
DATED OCTOBER 16, 1990

PART A: TECHNICAL PROPOSAL

MARCH 1991

Submitted to:

HAZWRAP SUPPORT CONTRACTOR OFFICE
OAK RIDGE, TENNESSEE 37831

Operated by:

MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY

Prepared by:

E.C. JORDAN CO.
PORTLAND, MAINE 04112

SITE INVESTIGATION ACTIVITIES
AND PROJECT COMMUNITY RELATIONS

SUFFOLK COUNTY AIR NATIONAL GUARD BASE
WESTHAMPTON BEACH, NEW YORK

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- A minimum of 3 to 5 well volumes will be removed from the well with a submersible pump. Field parameters will be measured after each well volume is extracted. Purging will continue until the 3 to 5 volumes have been removed or the field parameters have stabilized.
- Samples will be collected with appropriate sampling devices and put into the appropriate containers depending on the analyte and the analytical method requirements.
- All samples shall be labeled with computer-generated labels which utilize a database sampling code for sample-tracking purposes. All samples will be preserved with the appropriate preservative and packed and shipped with the appropriate chain of custody.
- Key personnel for each round of sampling are two sampling technicians, full-time for at least 9 days.

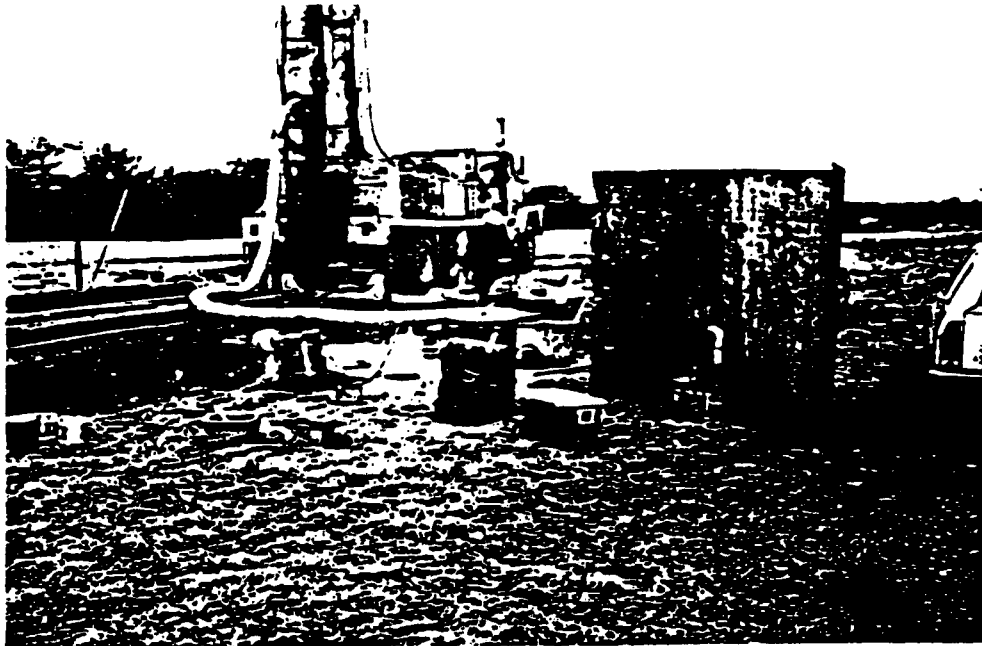
3.2.14.2 Site 7 - Fire Training Area. At the Internal Draft WP documents review meeting, HAZWRAP requested Jordan perform the following tasks at the FTA site.

- Extensively purge MW-107B until methyl ethyl ketone (MEK) is nondetectable by field GC analyses. This assumes MEK concentrations decrease as expected; if they do not decrease, then MEK is probably present in the groundwater.
- At least three, and no more than five, water samples from MW-107B will be sent to the laboratory for analyses. Samples will be taken, at a minimum: 1) prior to purging, 2) at mid-purging, and 3) upon completion of purging.
- Purge monitoring wells MW-201 (upgradient), MW-107A, and MW-107C three times in accordance with normal Jordan well-purging procedures. Field analyses of water samples from these wells will be performed to confirm that MEK is not present. One sample from each well will be sent to the laboratory for analyses.
- All laboratory analyses will be for TCL, VOCs using Level D data quality objectives.
- It is assumed that this sampling effort will require two days to complete by two sampling technicians.

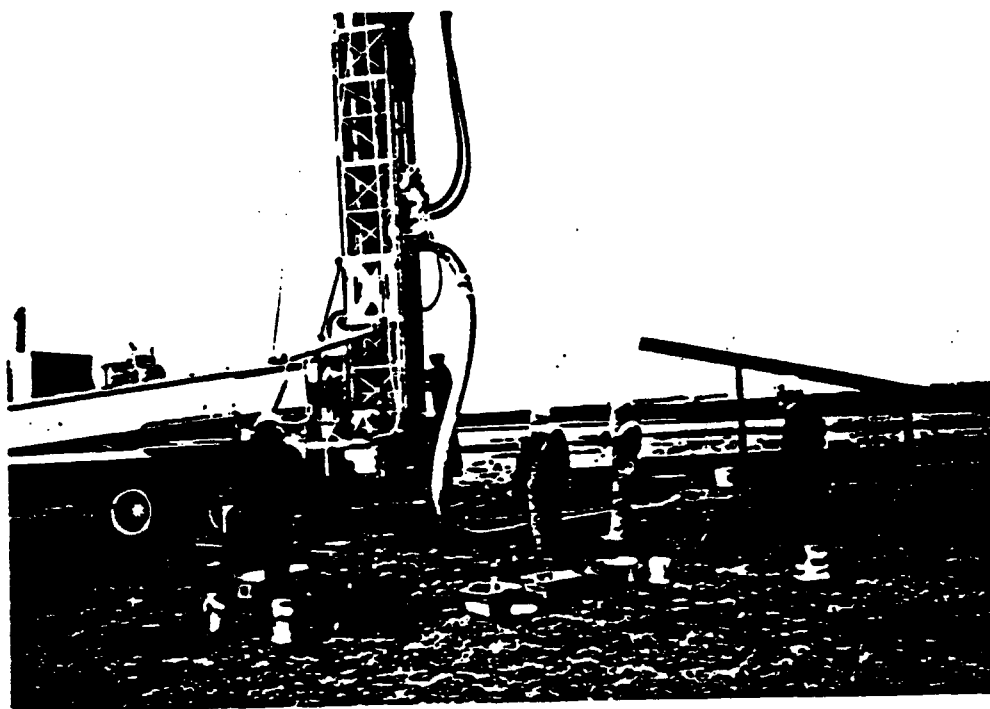
3.2.15 Permeability Testing

Permeability testing will be conducted in wells from Sites 1 through 5, and Site 9, and all piezometers. Variable falling or rising head permeability tests will be performed, depending on the hydraulic conductivity of the medium being tested and the relation of slot openings to the groundwater surface. Variable-head permeability tests will be conducted using a pressure transducer and data logger.

ATTACHMENT G



PHOTOGRAPH TAKEN IN FEBRUARY-MARCH 1987 OF DRILLING OF ONE OF THE MW-107 WELLS. NOTE THE DECONTAMINATION STATIONS SET-UP IN THE FOREGROUND. SPLIT SPOON SAMPLES ARE EXTRACTED AND PLACED ON PLASTIC ON TOP OF COOLER (RIGHT), THEN SCRUBBED WITH LIQUINOX AND WATER (CENTER) AND FINALLY ISOPROPANOL AND WATER (INSIDE SPRAYERS, LEFT). ALSO NOTE STAINLESS STEEL BUCKET TO CONTAINERIZE THE FLUIDS FROM THE ISOPROPANOL RINSE AND TO POUR ALL DECONTAMINATION FLUIDS INTO THE DRUM.



PHOTOGRAPH OF DRILLING AT ANOTHER LOCATION AT THE FTA. AGAIN NOTE THE SET-UP OF THE DECONTAMINATION FACILITY. SAMPLES ARE PLACED ON THE TABLE PRIOR TO DECONTAMINATION IN AN IDENTICAL MANNER. THE 55-GALLON DRUM IS MISSING AT THIS SITE AS ALL FLUIDS WERE TAKEN TO THE ONE DRUM THAT WAS LATER REMOVED BY THE BASE.

ATTACHMENT H

36,157

BILLED MAY 9 1987

Client -

Fraser Paper

R.G. Greiber

Guilford

Hannaford Bros.

Hannaford Bros.

Hartland Corp

Ivory Tanning

James River

Martin Marietta

Martin Marietta

Martin Marietta

Martin Marietta

Martin Marietta

Martin Marietta

Job #

5200-00

1 Bottle, 60 ml Acid

121910

2 Bottles

5201-02

20 Bottles, 4 pr. Gloves, 500ml TSP

5200-03

50 Bottles, 4 pr. Gloves, 3 gal. Alcohol,

3 gal DC water, 2 Roll Tape, 2 pens,

2 Sprayers

4791-01

13 Bottles

4791-02

12 Bottles

4091-07

20 Bottles, 30 pr. Gloves, 1 gal pH Buffers,

2 Cont. Stds, 25' tubing, 500ml Acid,

5 gal Alcohol, 1 gal. HNO₃, 1 Roll pH

Paper, 1 pkg. Miller Paper, 10 gal DC

Water, 1 Roll Tape, 2 Sprayers,

2 Squir Bottles, 1 pipet.

1919-52

12 Bottles,

1919-72

732 Bottles, 100 pr. Gloves, 20 gal.

Methanol, 32 Roll Tape, 2 Sprayers,

1 Brush, 3 Tubs

4919-72

100 Bottles, 100 pr. Gloves, 4 gal. DC

Water, 2 pens, 1 Squir Bottle

4919-72

170 Bottles, 5 gal DC Water, 1 Squir Bottle

4919-7

195 Bottles, 1 gal HNO₃, 5 Rolls

Tape, 10' Bullhick, 2 garden Sprayers

4919-02

694 Bottles, 20 pr. Gloves, 3 Tyvek suits,

6 Bottles, 10 Cartridges, 19 pr. Nibs, 5 gal.

TSP, 100 pr. Gloves, 1 pkg. 11 paper, 50 gal. DC

Water, 11 Roll, 10 pr. Gloves, 50' Bullh

150 -

450

950

108 -

31720

61 -

4450

55450

4570

179543

60924

27970

41807

150 -

450

950

108 -

31720

61 -

4450

55450

4570

179543

60924

27970

41807

150 -

450

950

108 -

31720

61 -

4450

55450

4570

179543

60924

27970

41807

ATTACHMENT I

AFFIDAVIT OF THOMAS LONGLEY

I am furnishing this Affidavit for the purpose of recording my knowledge of well drilling activities which we conducted in 1987 at the Suffolk County Airport under contract of E.C. Jordan Co. with Martin Marietta Energy Systems (HAZWRAP). All of the following statements are made of my own personal knowledge.

1. At all times relevant herein, I was employed by E.C. Jordan Co. In 1987 I was field geologist for the Suffolk County Airport program. As field geologist I was responsible for the collection of soil samples.
2. As field geologist at the Suffolk County Airport site, I was familiar with procedures used for decontamination of equipment utilized in field investigation.
3. I was present and have knowledge of the drilling of four monitoring wells (MW-101A through MW-107C), four piezometers (P-1 through P-4) and nine test borings (JTB-1 through JTB-9). At the Suffolk County Airport two of these twenty three exploratory borings were drilled using augers or casings that were supplied by a drilling subcontractor John Mathes and Associates of Columbia, Illinois, and were drilled under my direct supervision.
4. All of the drilling tools used on site were cleaned prior to drilling by hot water, high pressure washing system. The water was obtained from a fire hydrant on the airport property.
5. Between borings all the used equipment was again cleaned in the same manner. Cleaning was done on a concrete hardstand used as a staging area located south of the taxi-way and approximately 700 feet from the fire training area of the Suffolk County Airport.
6. All water that was used for these cleansings was allowed to either evaporate or seep into the surrounding soil.
7. During the drilling of most of the borings, split spoon samples were collected of the subsurface soil. Borings that were drilled and not sampled with the split spoon sampler include MW-105, MW-106, MW-107C, P-1, P-2, P-3 and P-4.
8. The split spoons were cleansed immediately after collection of the samples by being washed in soapy water, rinsed in potable water, rinsed with isopropyl alcohol and finally rinsed with distilled deionized water. Isopropyl alcohol and distilled water rinses were collected in a wash tub. The collected liquids were placed in a 55 gallon drum for future disposal off site.
9. The soapy water and potable rinse water were poured on the ground and allowed to percolate into soils at the individual soil boring locations.

10. Equipment decontamination, disposal of waste and decontamination materials are listed and/or discussed on pages C-6, C-7 and C-10 of the summary site safety plan. These procedures were followed during the field drilling program with the exception that (i) the alcohol rinse and final distilled deionized water rinse was collected and placed in a 55 gallon drum for collection, and (ii) approximately 5 gallons of isopropanol was brought to the site, in contrast to the stated 85 gallons on page C-10.

11. Methalhydrate was not used or brought on the site during the drilling program.

SIGNED UNDER PAINS AND PENALTIES OF PERJURY.

Deane Powers
Witness

Dated: 3/2/93

Thomas L. Longley
Thomas Longley

Dated: 3-2-93

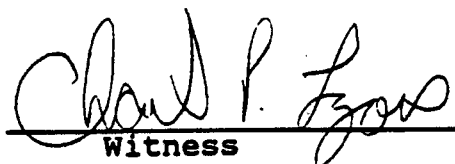
ATTACHMENT J

AFFIDAVIT

I, the undersigned Vicki S. Miller, do state as follows:

1. I am furnishing this Affidavit for the purpose of recording my knowledge of groundwater sampling activities which were conducted the week of February 5, 1989 at the Suffolk County Airport under contract of E.C. Jordan with Martin Marietta Energy Systems (HAZWRAP). All of the following statements are made of my own personal knowledge.
2. At the relevant time, I was employed by E.C. Jordan Co. as an environmental technician. My responsibilities included the purging and sampling monitoring wells, and equipment decontamination.
3. As an environmental technician, I am familiar with all field procedures associates to groundwater sampling.
4. I was present and have knowledge of the purging and sampling of 22 monitoring wells (P-1, P-2, P-3, P-4, MW-101A, MW-101B, MW-102, MW-103, MW-104, MW-105, MW-106, MW-107A, MW-107B, MW-107C, MW-00X, Mw-9, MW-10, MW-11, MW-14, MW-22, MW-23, MW-24) on February 5 through February 10, 1989. All of the wells were purged with either a submersible Keck pump or with a stainless steel bailer. In each case the pump or bailer was decontaminated prior to purging activities.
5. Decontamination consisted of flushing the inside of the pump or bailer with Methyl hydrate followed by a deionized water rinse. The exterior of the pump tubing or bailer was then sprayed with a 50% deionized water, 50% Methyl hydrate solution, followed by a deionized water rinse.
6. Each of the 22 wells mentioned above were sampled, after the completion of purging activities, using a stainless steel bailer. Prior to sampling the bailer was sprayed on the inside and outside with a 50/50 solution of deionized water and Methyl hydrate.
7. All decontamination fluids and rinse water were discharged on to the ground and allowed to percolate into the soils near the specific monitoring well locations.
8. The submersible pump decontamination required approximately one to two liters of Methyl hydrate for decontamination. Each bailer decontamination required the use of approximately 200 ml. of undiluted Methyl hydrate.
9. The total amount of methyl hydrate used in the sampling episode (prior to dilution as outlined above) was approximately 12 gallons.

Signed under the pains and penalties of perjury this 14 day of April, 1993.


Witness


Vicki S. Miller

jwapril\miller.aff

AFFIDAVIT

I, the undersigned Brad Schoonard, do state as follows:

1. I am furnishing this Affidavit for the purpose of recording my knowledge of groundwater sampling activities which were conducted the week of April 27, 1987 at the Suffolk County Airport under contract of E.C. Jordan with Martin Marietta Energy Systems (HAZWRAP). All of the following statements are made of my own personal knowledge.

2. At the relevant time, I was employed by E.C. Jordan Co. as an environmental technician. My responsibilities included the purging of monitoring wells, sample collection and equipment decontamination.

3. As an environmental technician, I am familiar with all field procedures associated to groundwater sampling.

4. I was present and have knowledge of the purging and sampling of ten monitoring wells on April 29 through April 30, 1987. Four of the wells (MW-101A, MW-102, MW-107A, MW-107B) were purged with a Keck or Fultz submersible pump. In each case the pump was decontaminated prior to purging activities. Decontamination consisted of flushing the inside of the pump with methyl hydrate followed by a deionized water rinse. The exterior of the pump tubing was then sprayed with a 50% deionized water, 50% methyl hydrate solution, followed by a deionized rinse.

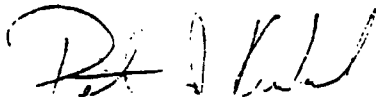
6. Each of the four wells mentioned above were sampled, after the completion of purging activities, using a stainless steel bailer. Prior to sampling the bailer was sprayed on the inside and outside with a 50% deionized water, 50% methyl hydrate solution, followed by a deionized water rinse.

7. All decontamination fluids and rinse water were discharged on to the ground and allowed to percolate into the soils near the individual monitoring well locations.

8. Each submersible pump decontamination required approximately one to two liters of Methyl hydrate for decontamination. Each bailer decontamination required the use of approximately 200 ml. of undiluted Methyl hydrate.

9. The total amount of methyl hydrate used in the sampling episode (prior to dilution as outlined above) was approximately 2 gallons.

Signed under the pains and penalties of perjury this 14 day of April, 1993.



Witness
PETER J. KUNKEL



Brad Schoonard

jwapril\schoonar.aff

AFFIDAVIT

I, the undersigned John Planinsek, do state as follows:

1. This Affidavit pertains to groundwater sampling events that took place at Suffolk County Airport from 1987 through 1989. During this time period, I was employed as an environmental technician for E.C. Jordan Co.

2. During this time period the standard operating protocol for decontaminating downhole sampling equipment used at the Suffolk County Airport was as follows.

A. Water level meter - Spray with a mixture of 50:50 methyl hydrate and deionized water solution followed by a straight deionized water rinse.

B. Submersible pump - Pump through the tubing approximately one (1) gallon of 50:50 methyl hydrate deionized water solution followed by another gallon of straight deionized water. Spray the exterior of the tubing with the methyl hydrate deionized water solution followed with a straight deionized rinse.

C. Bailers - Bailers were decontaminated in the same manner. The bailers were sprayed down first with the 50:50 methylhydrate/deionized water solution followed with straight deionized water.

3. These decontamination procedures took place adjacent to the monitoring wells sampled. The decontamination fluids were not containerized but were allowed to discharge to the ground.

4. The total amount of methyl hydrate (prior to dilution as described above) was approximately 2 gallons for Round 1, approximately 6 gallons for Round 2, and approximately 12 gallons for Round 3.

Signed under the pains and penalties of perjury this 14 day of April, 1993.

Sharon B Sneed
Witness

John Planinsek
John Planinsek

March 25, 1993

AFFIDAVIT FROM CHARLES D. GOODWIN

I have prepared this affidavit to provide , to the best of my recollection, the course of events that occurred during two rounds of ground water sampling episodes I participated in at Suffolk County Airport, Long Island, New York. The Company, then known as E.C. Jordan, was under contract to Martin Marietta Energy Systems (ORNL). This statement has been prepared from personal recall, a review of Company time report sheets from the weeks in question, and a review of two copies of Field Sample Data Records (one from each of the episodes in question).

The first sampling episode was conducted the week of Monday, April 27 through Friday, May 1, 1987. A synopsis of events, as I recall them, follows:

Monday, April 27 : The three person sampling crew mobilized the sampling vehicle and equipment, etc. from Portland, ME. They drove to New London, CT and took the Cross Sound Ferry to Orient the Best Western Motel.

Tuesday, April 28: The sampling crew arrived on site, conducted a round of ground water measurements, and initiated sampling activities. I believe an auditor/observer from ORNL, a Mr. Charles Turner, was also on site this day and remained with the sampling crew the remainder of the field sampling episode. The monitoring wells were initially purged with submersible pumps and sampled using stainless steel bailers. The two pumps eventually failed, and the remainder of the wells were purged and sampled using stainless steel bailers.

Wednesday, April 29: A round of ground water elevation measurements in selected wells and piezometers was conducted, and followed by a continuation of monitoring well sampling. The wells were purged and sampled using stainless steel bailers. The ORNL representative remained with the sampling crew throughout the day.

Thursday, April 30: A round of ground water elevation measurements was initially conducted, and the monitoring well sampling effort continued. The sampling program concluded this day.

Decontamination procedures for all sampling equipment was conducted using protocols which included:

Pumps were deconned prior to any well purging activities. The pump unit and inner pump tubing were first flushed with a solution of methyl hydrate and water, followed by a deionized water flush. Approximately one liter of methyl hydrate was mixed with three gallons of deionized water for the first

04/14/83

07:53

207 772 4782

ABB PORTLAND ME

Signed under the pains and penalties of perjury this 14 day of April, 1993.

Lisa M. Roethlisberger
Witness

Charles D. Goodwin
Charles D. Goodwin

ATTACHMENT K

Source:

GWFLOW - INTERNATIONAL
GROUNDWATER MODELING CENTER
VERSION: BASK 2.0, 1987
By: Paul K.M. van der Haaij

----- GWFLOW01 -----
NONSTEADY STATE FLOW IN A HOMOGENEOUS, ISOTROPIC, NONLEAKY CONFINED AQUIFER
WITH A SINGLE PRODUCTION OR INJECTION WELL

Enter transmissivity - T [gpd/ft]: 48133

Enter storage coefficient - S [fraction]: .3

Enter pumping rate - Q (injection is negative) [gpd]: 1440

Enter time since pumping started - t [days]: .125

Enter radius - r (= distance between observation
and pumping well) [ft]: .083

----- RESULTS -----

u = 6.424276E-07

W(u) = 13.6808

Drawdown s = 0.033[ft]

SOURCE:
 GROUNDWATER Pumping TESTS
 DESIGN & ANALYSIS BY:
 WILLIAM C. WALTON
 1987 by LEWIS PUBLISHERS
 PT I: Pumping TEST DESIGN MODEL

DATA BASE:

AQUIFER HORIZ. HYDR. COND. (GPD/SQ FT) = 740.50
 AQUIFER VERT. HYDR. COND. (GPD/SQ FT) = 74.000
 AQUIFER THICKNESS (FT) = 65.00
 ARTESIAN AQUIFER STORATIVITY (DIM) = 1.0000D-05
 WATER TABLE STORATIVITY (DIM) = 0.3000
 PRODUCT. WELL EFFECTIVE RADIUS (FT) = 0.083
 TOP OF AQUIFER DEPTH (FT) = 0.00
 BASE OF AQUIFER DEPTH (FT) = 65.00
 INITIAL WATER LEVEL DEPTH (FT) = 0.00
 INFINITE AQUIFER SYSTEM

COMPUTATION RESULTS:

PRODUCTION WELL DISCHARGE RATE (GPM) = 1.00

TIME-DRAWDOWN OR WATER LEVEL VALUES (FT)

TIME(MIN)	SELECTED DISTANCES (FT)					
	0.08	13.15	33.04	83.00	208.49	523.69
0.15	0.04	0.01	0.01	0.01	0.00	0.00
0.24	0.04	0.01	0.01	0.01	0.00	0.00
0.39	0.04	0.02	0.01	0.01	0.00	0.00
0.61	0.04	0.02	0.01	0.01	0.00	0.00
0.97	0.04	0.02	0.01	0.01	0.00	0.00
1.53	0.04	0.02	0.01	0.01	0.00	0.00
2.43	0.04	0.02	0.01	0.01	0.00	0.00
3.85	0.04	0.02	0.01	0.01	0.00	0.00
6.11	0.04	0.02	0.01	0.01	0.00	0.00
9.68	0.04	0.02	0.01	0.01	0.00	0.00
15.34	0.04	0.02	0.01	0.01	0.01	0.00
24.32	0.04	0.02	0.01	0.01	0.01	0.00
38.54	0.04	0.02	0.01	0.01	0.01	0.00
61.08	0.04	0.02	0.01	0.01	0.01	0.00
96.81	0.04	0.02	0.01	0.01	0.01	0.00
153.43	0.04	0.02	0.01	0.01	0.01	0.00
180.00	0.04	0.02	0.01	0.01	0.01	0.00

TIME AFTER PUMPING STARTED(MIN) = 180.00

DISTANCE-DRAWDOWN OR WATER LEVEL VALUES AT END OF PUMPING PERIOD

NODE NO	RADIUS(FT)	DRAWDOWN OR WATER LEVEL (FT)
2	0.08	0.04
3	0.13	0.04
4	0.21	0.04
5	0.33	0.04
6	0.52	0.03
7	0.83	0.03
8	1.32	0.03
9	2.08	0.03
10	3.30	0.03
11	5.24	0.02
12	8.30	0.02
13	13.15	0.02
14	20.85	0.02
15	33.04	0.01
16	52.37	0.01
17	83.00	0.01
18	131.55	0.01
19	208.49	0.01
20	330.43	0.00
21	523.69	0.00

10/2/91 GAC (2)
 201A. 2:15 MW201A; FTMW 201A0102XX
 T.P. = Not Above Background (NAB)
 Depth to Water = 35.91' Depth to Bottom of Well = 66.77'
 $35.26' - 66.77' = -31.51'$ W/c = -1.65'
 Slickup = 2.4' Water Column = $\frac{35.91}{31.51} = 1.14$
 Vol. = $14(31.86) = 446.04 \approx 5.1$ gallons

Well bent @ 10' H down - unable to salvage 2" bailer or pump.

12:33 Leaving 201A.
 12:46 FTMW 107A0102XX

TIP = 7.9 (ambim!) TIP = 7.2 (in well). Depth to Water = 31.69'. Depth to Bottom of Well = 153' (stickup) = 2.9' w/c = -2.2'
 Water Column = 153' 1 Well Vol. = $\frac{115}{31.69} = 3.63$

14(115) = 1610 gal. 107 Collected first sample @ 12:54. JP bringing it to lab while we purge 107A. Hook

10/2/91 Julie P. Cunniff (3)
 After purging 1 well vol. Andolskek m.c. & Temp = 13.0°C
 SC = 0.07 x 20 = 1.4 m/c/gac pH = 7.38
 mV = 002 After purging the 2nd Well Vol:
 Temp = 12.7°C pH = 7.8. 2:20. Took 4 well samples - FTMW 107A0302XX.

12:30 I leave site Julie P. Cunniff
 HPI well take over

10/3/91 Julie P. Cunniff
 107B 8:53 JP has taken the first sample already. Depth to H₂O = 37.31'. Depth to Bottom = 105' Water Col. $\frac{105}{37.31} = 2.81$
 1 Well Vol = $\frac{162}{2.81} = 57.65$ gal. HPI JP left site. 12:25 The plan is to take

pH, temp, m.c. and, of course each well vol. is purged. Take a sample after every five well vol. until MEK disappears. 1 gal = 1 min.
 1st W.V: pH = 7.61 Temp = 12.7°C Cond. = 0.71 m

10/3/91 JAC

④

9:15 2nd WV: pH=10.17 Temp=12.6°C Cond=.069

Discharge area for pumped H₂O located ~

12 ft South (down gradient) of well.

Stickup=3.2 W/C=.18

9:26 3rd WV: pH=9.47 Temp=12.6°C

Cond=.070 mS/cm

9:37 4th WV: pH=8.87 Temp=12.6°C

Cond=.071

Sample #FTMW107B0202XX Taken after

9:40 4th WV purged the label is the

identical time of 8:55 at it.

9:45 Pumping Begins again.

9:56 5th WV: pH=9.99 Temp=12.6°C

Cond=.057 10:07 6th WV: pH=9.50

Temp=12.5 Cond=.058

10:18 7th WV: pH=8.20 Temp=12.6°C

Cond=.058 10:29 8th WV: pH=7.53

Temp=12.6 Cond=.059

TIP=NAB

10/3/91 JAC

⑤

107C Depth to H₂O=37.68 TIP=NAB

Depth to Bottom = 51.0' Water Column =

$\frac{51.0}{1.4} = 13.32'$ Well Vol. $\frac{13.32}{2} = 2.2$ gal.

W/C=-0.20'

Stickup=3.15

Sample taken @ 107B after 2th

Well Vol. #FTMW107B0302XX

107B 10:49 9th WV: pH=7.19

Temp=12.5 Cond=.075 mS/cm

11:00 10th WV: pH=7.17 Temp=12.5

Cond=.075 11:14 11th WV: pH=7.10

Temp=12.6 Cond=.075

Collect Sample #FTMW107B0402XX @

11:14 11:30 12th WV: pH=6.85

Temp=12.8 Cond=.060 11:41 13th WV

11:45 Discontinue Pumping/Purging. Clear

As per GC. Final Readings. pH=6.25

Temp=12.8 Cond=.065

PROJECT	CAPITOL CONC RT MW-1078	COMP BY	JOB NO.
	SCANGB - FTA	RL	6943-61
		CHK BY	DATE
			2-5-93

$$K = 99 \text{ ft/day}$$

$$b = 65 \text{ ft}$$

$$Q = 1440 \text{ Gal/day} = 192.5 \frac{\text{ft}^3}{\text{day}}$$

$$I = 0.0023$$

Source: (Bear, 1972)

Flow net for production well in regional flow

$$\text{STAG. PT.} = x_L = -\frac{Q}{2\pi K b i}$$

$$x_L = \frac{192.5 \text{ ft}^3/\text{day}}{2\pi (6,435 \text{ ft}^3/\text{day}) 0.0023}$$

$$x_L = 2.07 \text{ ft} = \text{stagnation point downgradient from well}$$

$$\text{Zone of capture upgradient of well} = 2\pi x_L$$

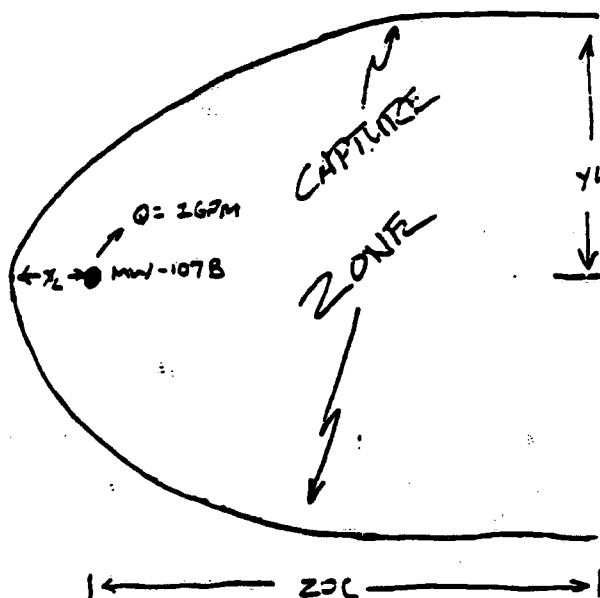
$$ZOC = 2\pi (2.07 \text{ ft})$$

$$ZOC = 13.0 \text{ ft upgradient}$$

$$\frac{1}{2} \text{ width of capture} = y_L = \left(\frac{Q}{2Kbi} \right)$$

$$y_L = \left(\frac{192.5 \text{ ft}^3/\text{day}}{29.60 \text{ ft}^3/\text{day}} \right)$$

$$y_L = 6.5 \text{ ft}$$



←
GW FLOW DIRECTION
←

PROJECT SCAN 6 B - FTA	COMP BY RL	JOB NO. 67-13-61
	CHK BY	DATE 2-5-93

MW-107B	DIA.	DEPTH	SCREENED INTERVAL	DTW (FROM BENTON LOG)
	2"	100'	85-100'	35'

VOL. OF H₂O IN WELL = 100 - 35 = 65 FT STANDING COLUMN.

VOL. OF CYLINDER = $\pi R^2 H (7.48)$ IN GALLONS

$$\therefore V = \pi (0.0069 \text{ ft}^2) (65 \text{ ft}) (7.48 \frac{\text{gal}}{\text{ft}^3})$$

$$VOL = 10.6 \text{ GAL. / CASING VOL.}$$

* DURING ROUND 5, APPROXIMATELY 180 GALLONS WERE PURGED

SOLVE FOR (R) ASSUMING VOL = 180 GAL. =

$$VOL = \pi R^2 H (7.48)$$

$$\sqrt{\frac{VOL}{\pi H (7.48)}} = R$$

H = SCREENED INTERVAL

$$\sqrt{\frac{180}{\pi (15) (7.48)}} = R$$

$$0.71 \text{ ft} = R$$

1.43 ft = Diameter of water column removed

ATTACHMENT M

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*****
*
*      INTERNATIONAL GROUND WATER MODELING CENTER
*      Indianapolis, USA - Delft, The Netherlands
*
*      S O L U T E   version 2.00
*
*      ANALYTICAL MODELS FOR SOLUTE TRANSPORT
*
*****

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PROJECT..... = Suffolk Cty ANG
USER NAME..... = R. Lewis
DATE..... = 02-08-1993
DATA FILE..... =

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INPUT DATA:

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GROUNDWATER (SEEPAGE) VELOCITY.... = .76 [ft/d]
POROSITY..... = .3
LONGITUDINAL DISPERSIVITY..... = 10 [ft]
LATERAL DISPERSIVITY..... = 1 [ft]
VERTICAL DISPERSIVITY..... = .1 [ft]
HALF-LIFE..... = 0 [d]
NUMBER OF POINT SOURCES..... = 1

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SOURCE NO. 1

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X-COORDINATE OF THE SOURCE..... = 0 [ft]
Y-COORDINATE OF THE SOURCE..... = 0 [ft]
Z-COORDINATE OF THE SOURCE..... = 0 [ft]
TOTAL SOLUTE MASS INJECTED..... = .005 [lb]
ELAPSED TIME..... = 3947 [d]

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GRID DATA:

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X-COORDINATE OF GRID ORIGIN..... = 0 [ft]
Y-COORDINATE OF GRID ORIGIN..... = 0 [ft]
Z-COORDINATE OF GRID ORIGIN..... = 0 [ft]
DISTANCE INCREMENT DELX..... = 100 [ft]
DISTANCE INCREMENT DELY..... = 10 [ft]
DISTANCE INCREMENT DELZ..... = 1 [ft]
NUMBER OF NODES IN X-DIRECTION.... = 40
NUMBER OF NODES IN Y-DIRECTION.... = 10
NUMBER OF NODES IN Z-DIRECTION.... = 1

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ATTACHMENT L

③

①

10/21/91 Julie O. Currie

John Plamondon

10:10 Arrive @ ETA and set up the sample wells.

10:26 ETMW101A XXX

TIP = 8.5 (ambient) TIP = 8.5 (well head)

Depth to H₂O = 37.15' Depth to

Bottom = 156' Water Column = 119'

.14 (119) = $\frac{119}{71.7} = 1.66$ vol.

Top of Casing = 20' Well/Casing = 12'

10:30 Took 3 VJA samples. TP

delivered them to GC lab where

we started the run. 11:05 well

has a bind in the H₂O table

pump hose can't descend down

the well any further. 11:2

Purging the well. Slow process 11:2

of the location of pump. 11:30

pugged. 12:02 Discontinue purging

10:1A - GC says clean: none to

ROW\COLUMN			16	17	18	19	20
		[ft]	1500.00	1600.00	1700.00	1800.00	1900.00
1	0.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
2	10.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
3	20.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
4	30.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
5	40.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
6	50.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
7	60.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
8	70.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
9	80.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
10	90.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000

ROW\COLUMN			21	22	23	24	25
		[ft]	2000.00	2100.00	2200.00	2300.00	2400.00
1	0.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
2	10.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
3	20.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
4	30.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
5	40.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
6	50.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
7	60.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
8	70.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
9	80.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
10	90.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000

ROW\COLUMN			26	27	28	29	30
		[ft]	2500.00	2600.00	2700.00	2800.00	2900.00
1	0.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
2	10.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
3	20.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
4	30.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
5	40.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
6	50.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
7	60.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
8	70.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
9	80.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
10	90.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000

CONCENTRATION C [mg/l] - LAYER 1

ROW\COLUMN			1	2	3	4	5
			[ft]				
				0.00	100.00	200.00	300.00
							400.00
1	0.00	[ft]	-0.0000	0.0000	0.0000	0.0000	0.0000
2	10.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
3	20.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
4	30.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
5	40.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
6	50.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
7	60.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
8	70.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
9	80.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
10	90.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000

ROW\COLUMN			6	7	8	9	10
			[ft]				
				500.00	600.00	700.00	800.00
							900.00
1	0.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
2	10.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
3	20.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
4	30.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
5	40.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
6	50.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
7	60.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
8	70.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
9	80.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
10	90.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000

ROW\COLUMN			11	12	13	14	15
			[ft]				
				1000.00	1100.00	1200.00	1300.00
							1400.00
1	0.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
2	10.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
3	20.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
4	30.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
5	40.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
6	50.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
7	60.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
8	70.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
9	80.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
10	90.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000

ROW\COLUMN			31	32	33	34	35
			[ft]				
			3000.00	3100.00	3200.00	3300.00	3400.00
1	0.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
2	10.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
3	20.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
4	30.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
5	40.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
6	50.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
7	60.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
8	70.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
9	80.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
10	90.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000

ROW\COLUMN			36	37	38	39	40
			[ft]				
			3500.00	3600.00	3700.00	3800.00	3900.00
1	0.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
2	10.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
3	20.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
4	30.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
5	40.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
6	50.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
7	60.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
8	70.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
9	80.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
10	90.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000

PROJECT Suffolk Co. ANG - FTA	COMP. BY RAL	JOB NO. 6943-61
	CHK. BY RHA	DATE 2-8-93

1062

$$\rho(\text{2-Butanone}) = 0.8047 \text{ g/cm}^3 \quad [\text{EPA/600/8-90/003}]$$

Total volume contained in well bore of

$$\text{length} = 100 - 35 = 65 \text{ ft}$$

$$\text{diameter} = 2" = \frac{1}{6} \text{ ft} \Rightarrow r = \frac{1}{12} \text{ ft}$$

$$V = \pi r^2 h = \frac{\pi (65)}{144} \text{ ft}^3 = 1.42 \text{ ft}^3$$

Mass of 2-Butanone in well bore @ 56 ppm

$$M_0 = (1.42 \text{ ft}^3) (62.4 \frac{\text{lb}}{\text{ft}^3}) \left(\frac{56}{10^6} \right) = 0.00496 \text{ lb}$$

say 0.005 lb

Mass of 2-Butanone in 85 gal. methyl hydrate
@ 3% by volume 2-butanone

$$M = (0.03) (85 \text{ gal}) \left(\frac{1 \text{ ft}^3}{7.48 \text{ gal}} \right) (0.8047) (62.4 \frac{\text{lb}}{\text{ft}^3})$$

$$= 17.1 \text{ lb 2-butanone}$$

Assume each of these masses is introduced as a slug into the aquifer.

Assume dispersivities of $\begin{cases} \alpha_x = 10 \text{ ft} \\ \alpha_y = 1 \text{ ft} \\ \alpha_z = 0.1 \text{ ft} \end{cases}$
as conservative estimates

[EPA rule of thumb would give $\begin{cases} \alpha_x \approx 300 \text{ ft} \\ \alpha_y \approx 100 \text{ ft} \\ \alpha_z \approx 10 \text{ ft} \end{cases}$]

PROJECT Suffolk Co. ANG-FTA	COMP. BY RAL CHK. BY RHL	JOB NO. 6943-61 DATE 2-8-93
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2 of 2

Results:

With no attenuation/retardation, the mass of 0.005# 2-butanone in the well, if injected instantly into the aquifer would result in no detectable concentrations at the well field. (See Slug 3D output), i.e., concentration <0.1 ppb.

Similarly, with a spill of 85 gallons of methyl hydrate at 3% 2-butanone, if injected instantly, with no retardation/attenuation (even of volatilization in the 35-foot unsaturated zone) yielded a concentration of 2-butanone of 0.1248 mg/L.

Note that only a small fraction of the hypothetical 85 gallons of methyl hydrate would be expected to reach the groundwater table (due to volatilization losses), and would certainly be spread out over a much longer time frame than, say 1 day (instantly). Spreading this release over a longer time would proportionately decrease concentrations, both initially at the source and downgradient at the well field.

The hypothetical case of an 85-gallon spill has been assumed only to establish a worst case scenario.

An additional run was made with the travel distance of 4000 ft as per NYSDOL (p.4, 1st ft). At this distance, the worst case concentration was: 0.081 mg/L.

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*      INTERNATIONAL GROUND WATER MODELING CENTER
*      Indianapolis, USA - Delft, The Netherlands
*
*      S O L U T E   version 2.00
*
*      ANALYTICAL MODELS FOR SOLUTE TRANSPORT
*
*****

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PROJECT..... = SCANGB FTA
USER NAME..... = H. ANDOLSEK
DATE..... = 03-26-1993
DATA FILE..... =

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INPUT DATA:

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GROUNDWATER (SEEPAGE) VELOCITY.... = .76 [ft/d]
POROSITY..... = .3
LONGITUDINAL DISPERSIVITY..... = 10 [ft]
LATERAL DISPERSIVITY..... = 1 [ft]
VERTICAL DISPERSIVITY..... = .1 [ft]
HALF-LIFE..... = 0 [d]
NUMBER OF POINT SOURCES..... = 1

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SOURCE NO. 1

```

X-COORDINATE OF THE SOURCE..... = 0 [ft]
Y-COORDINATE OF THE SOURCE..... = 0 [ft]
Z-COORDINATE OF THE SOURCE..... = 0 [ft]
TOTAL SOLUTE MASS INJECTED..... = 4.02 [lb]
ELAPSED TIME..... = 5263 [d]

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GRID DATA:

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X-COORDINATE OF GRID ORIGIN..... = 0 [ft]
Y-COORDINATE OF GRID ORIGIN..... = 0 [ft]
Z-COORDINATE OF GRID ORIGIN..... = 0 [ft]
DISTANCE INCREMENT DELX..... = 200 [ft]
DISTANCE INCREMENT DELY..... = 10 [ft]
DISTANCE INCREMENT DELZ..... = 1 [ft]
NUMBER OF NODES IN X-DIRECTION.... = 21
NUMBER OF NODES IN Y-DIRECTION.... = 10
NUMBER OF NODES IN Z-DIRECTION.... = 1

```

CONCENTRATION C [mg/l] - LAYER 1

ROW\COLUMN			1	2	3	4	5
			[ft]				
			0.00	200.00	400.00	600.00	800.00
1	0.00	[ft]	-0.0000	0.0000	0.0000	0.0000	0.0000
2	10.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
3	20.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
4	30.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
5	40.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
6	50.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
7	60.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
8	70.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
9	80.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
10	90.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000

ROW\COLUMN			6	7	8	9	10
			[ft]				
			1000.00	1200.00	1400.00	1600.00	1800.00
1	0.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
2	10.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
3	20.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
4	30.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
5	40.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
6	50.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
7	60.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
8	70.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
9	80.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
10	90.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000

ROW\COLUMN			11	12	13	14	15
			[ft]				
			2000.00	2200.00	2400.00	2600.00	2800.00
1	0.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
2	10.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
3	20.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
4	30.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
5	40.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
6	50.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
7	60.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
8	70.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
9	80.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
10	90.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000

ROW\COLUMN			16	17	18	19	20
			[ft]				
			3000.00	3200.00	3400.00	3600.00	3800.00

1	0.00 [ft]	0.0000	0.0003	0.0020	0.0070	0.0148
2	10.00 [ft]	0.0000	0.0003	0.0020	0.0070	0.0147
3	20.00 [ft]	0.0000	0.0003	0.0020	0.0068	0.0145
4	30.00 [ft]	0.0000	0.0003	0.0019	0.0066	0.0140
5	40.00 [ft]	0.0000	0.0003	0.0018	0.0063	0.0134
6	50.00 [ft]	0.0000	0.0003	0.0017	0.0060	0.0127
7	60.00 [ft]	0.0000	0.0003	0.0016	0.0056	0.0118
8	70.00 [ft]	0.0000	0.0003	0.0015	0.0052	0.0109
9	80.00 [ft]	0.0000	0.0002	0.0013	0.0047	0.0099
10	90.00 [ft]	0.0000	0.0002	0.0012	0.0042	0.0089

ROW\COLUMN		21
	[ft]	4000.00
1	0.00 [ft]	0.0190
2	10.00 [ft]	0.0189
3	20.00 [ft]	0.0186
4	30.00 [ft]	0.0180
5	40.00 [ft]	0.0172
6	50.00 [ft]	0.0163
7	60.00 [ft]	0.0152
8	70.00 [ft]	0.0140
9	80.00 [ft]	0.0128
10	90.00 [ft]	0.0115

*
* INTERNATIONAL GROUND WATER MODELING CENTER *
* Indianapolis, USA - Delft, The Netherlands *
*
* S O L U T E version 2.00 *
*
* ANALYTICAL MODELS FOR SOLUTE TRANSPORT *
*

PROJECT..... = SCANGB FTA
USER NAME..... = H. ANDOLSEK
DATE..... = 03-26-1993
DATA FILE..... =

INPUT DATA:

GROUNDWATER (SEEPAGE) VELOCITY.... = .76 [ft/d]
POROSITY..... = .3
LONGITUDINAL DISPERSIVITY..... = 10 [ft]
LATERAL DISPERSIVITY..... = 1 [ft]
VERTICAL DISPERSIVITY..... = .1 [ft]
HALF-LIFE..... = 0 [d]
NUMBER OF POINT SOURCES..... = 1

SOURCE NO. 1

X-COORDINATE OF THE SOURCE..... = 0 [ft]
Y-COORDINATE OF THE SOURCE..... = 0 [ft]
Z-COORDINATE OF THE SOURCE..... = 0 [ft]
TOTAL SOLUTE MASS INJECTED..... = 4.02 [lb]
ELAPSED TIME..... = 12775 [d]

GRID DATA:

X-COORDINATE OF GRID ORIGIN..... = 0 [ft]
Y-COORDINATE OF GRID ORIGIN..... = 0 [ft]
Z-COORDINATE OF GRID ORIGIN..... = 0 [ft]
DISTANCE INCREMENT DELX..... = 500 [ft]
DISTANCE INCREMENT DELY..... = 10 [ft]
DISTANCE INCREMENT DELZ..... = 1 [ft]
NUMBER OF NODES IN X-DIRECTION.... = 20
NUMBER OF NODES IN Y-DIRECTION.... = 10
NUMBER OF NODES IN Z-DIRECTION.... = 1

CONCENTRATION C [mg/l] - LAYER 1

ROW\COLUMN			1	2	3	4	5
[ft]			0.00	500.00	1000.00	1500.00	2000.00
1	0.00	[ft]	-0.0000	0.0000	0.0000	0.0000	0.0000
2	10.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
3	20.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
4	30.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
5	40.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
6	50.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
7	60.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
8	70.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
9	80.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
10	90.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000

ROW\COLUMN			6	7	8	9	10
[ft]			2500.00	3000.00	3500.00	4000.00	4500.00
1	0.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
2	10.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
3	20.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
4	30.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
5	40.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
6	50.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
7	60.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
8	70.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
9	80.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
10	90.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000

ROW\COLUMN			11	12	13	14	15
[ft]			5000.00	5500.00	6000.00	6500.00	7000.00
1	0.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
2	10.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
3	20.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
4	30.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
5	40.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
6	50.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
7	60.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
8	70.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
9	80.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
10	90.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000

ROW\COLUMN			16	17	18	19	20
[ft]			7500.00	8000.00	8500.00	9000.00	9500.00

1	0.00	[ft]	0.0000	0.0000	0.0001	0.0014	0.0045
2	10.00	[ft]	0.0000	0.0000	0.0001	0.0014	0.0045
3	20.00	[ft]	0.0000	0.0000	0.0001	0.0014	0.0045
4	30.00	[ft]	0.0000	0.0000	0.0001	0.0013	0.0044
5	40.00	[ft]	0.0000	0.0000	0.0001	0.0013	0.0043
6	50.00	[ft]	0.0000	0.0000	0.0001	0.0013	0.0042
7	60.00	[ft]	0.0000	0.0000	0.0001	0.0013	0.0041
8	70.00	[ft]	0.0000	0.0000	0.0001	0.0012	0.0040
9	80.00	[ft]	0.0000	0.0000	0.0001	0.0012	0.0038
10	90.00	[ft]	0.0000	0.0000	0.0001	0.0011	0.0037

PROJECT TITLE = SUFFOLK
JOB # = 0000088
DATE = 3/30/93
NAME = R. LEWIS

SOIL PROPERTIES

SOIL BULK DENSITY (G/CM3)	=	1.86
SOIL VOLUMETRIC WATER CONTENT (DIM)	=	.01
SOIL VOLUMETRIC AIR CONTENT (DIM)	=	.29
TOTAL SOIL POROSITY (DIM)	=	.3
FRACTION OF ORGANIC CARBON (DIM)	=	.001

TRANSPORT PROPERTIES

AIR BOUNDARY LAYER THICKNESS (CM)	=	1
INFILTRATION RATE (CM/DAY)	=	.125

CHEMICAL DATA

CHEMICAL NAME	=	2-BUTANONE
INITIAL CONCENTRATION (PPM)	=	3850
HENRY'S LAW CONSTANT (DIM)	=	.0012
ORGANIC CARBON PART COEF (CM3/G)	=	4.5
HALF LIFE (DAYS)	=	100
DEPTH TO TOP OF CONTAMINANTS (CM)	=	0
THICKNESS OF CONTAMINANT ZONE (CM)	=	30

CONCENTRATION (PPM) AS A FUNCTION OF TIME AND DEPTH

DEPTH (CM)	TIME (DAYS)				
	10.0	20.0	30.0	40.0	50.0
30.000	166.727	7.582	0.444	0.031	0.002
60.000	733.233	60.386	4.406	0.330	0.026
90.000	1069.814	231.781	23.902	2.143	0.186
120.000	610.530	514.936	86.168	9.906	0.999
150.000	143.243	698.030	217.673	34.441	4.218
180.000	14.027	590.930	394.470	92.219	14.324
210.000	0.575	316.210	519.308	192.581	39.604
240.000	0.010	107.679	500.325	316.009	89.843
270.000	-0.000	23.425	354.440	409.430	168.035
300.000	-0.000	3.262	185.204	420.213	259.957
330.000	-0.000	0.291	71.533	342.429	333.441
360.000	-0.000	0.018	20.453	221.928	355.217
390.000	-0.000	-0.000	4.333	114.532	314.695
420.000	-0.000	-0.000	0.681	47.112	232.084
450.000	-0.000	-0.000	0.080	15.457	142.591
480.000	-0.000	-0.000	0.007	4.046	73.029
510.000	-0.000	-0.000	-0.000	0.846	31.195
540.000	-0.000	-0.000	-0.000	0.141	11.117
570.000	-0.000	-0.000	-0.000	0.019	3.306
600.000	-0.000	-0.000	-0.000	0.002	0.821
630.000	-0.000	-0.000	-0.000	-0.000	0.170
660.000	-0.000	-0.000	-0.000	-0.000	0.030
690.000	-0.000	-0.000	-0.000	-0.000	0.005
720.000	-0.000	-0.000	-0.000	-0.000	-0.000
750.000	-0.000	-0.000	-0.000	-0.000	-0.000
780.000	-0.000	-0.000	-0.000	-0.000	-0.000
810.000	-0.000	-0.000	-0.000	-0.000	-0.000
840.000	0.000	-0.000	-0.000	-0.000	-0.000
870.000	0.000	-0.000	-0.000	-0.000	-0.000
900.000	0.000	-0.000	-0.000	-0.000	-0.000

approximate
depth to
water table →

CONCENTRATION (PPM) AS A FUNCTION OF TIME AND DEPTH

DEPTH (CM)	TIME (DAYS)				
	60.0	70.0	80.0	90.0	100.0
30.000	0.001	-0.000	-0.000	-0.000	-0.000
60.000	0.002	0.000	-0.000	-0.000	-0.000
90.000	0.016	0.001	-0.000	-0.000	-0.000
120.000	0.095	0.009	0.002	-0.000	-0.000
150.000	0.459	0.047	0.005	0.001	-0.000
180.000	1.828	0.210	0.023	0.002	0.000
210.000	6.106	0.802	0.096	0.011	0.001
240.000	17.224	2.647	0.355	0.044	0.005
270.000	41.233	7.569	1.162	0.159	0.020
300.000	84.059	18.813	3.353	0.514	0.071
330.000	146.270	40.755	8.569	1.496	0.229
360.000	217.625	77.087	19.420	3.904	0.671
390.000	277.222	127.471	39.086	9.160	1.780
420.000	302.652	184.464	69.937	19.343	4.294
450.000	283.406	233.797	111.341	36.789	9.420
480.000	227.772	259.701	157.811	63.067	18.810
510.000	157.198	252.958	199.249	97.498	34.205
540.000	93.201	216.147	224.193	135.981	56.674
570.000	47.488	162.082	224.892	171.168	85.587
600.000	20.800	106.693	201.179	194.521	117.843
630.000	7.833	61.668	160.535	199.627	147.975
660.000	2.537	31.305	114.294	185.047	169.499
690.000	0.707	13.959	72.616	154.967	177.139
720.000	0.169	5.468	41.178	117.265	168.933
750.000	0.035	1.882	20.845	80.190	147.037
780.000	0.006	0.569	9.420	49.564	116.819
810.000	0.001	0.151	3.801	27.692	84.727
840.000	-0.000	0.035	1.369	13.987	56.104
870.000	-0.000	0.007	0.441	6.387	33.921
900.000	-0.000	0.002	0.127	2.637	18.728

CONCENTRATION (PPM) AS A FUNCTION OF TIME AND DEPTH

DEPTH (CM)	TIME (DAYS)				
	110.0	120.0	130.0	140.0	150.0
30.000	-0.000	-0.000	-0.000	-0.000	-0.000
60.000	-0.000	-0.000	-0.000	-0.000	-0.000
90.000	-0.000	-0.000	-0.000	-0.000	-0.000
120.000	-0.000	-0.000	-0.000	-0.000	-0.000
150.000	-0.000	-0.000	-0.000	-0.000	-0.000
180.000	-0.000	-0.000	-0.000	-0.000	-0.000
210.000	-0.000	-0.000	-0.000	-0.000	-0.000
240.000	0.001	-0.000	-0.000	-0.000	-0.000
270.000	0.002	0.001	-0.000	-0.000	-0.000
300.000	0.009	0.001	-0.000	-0.000	-0.000
330.000	0.032	0.004	0.001	-0.000	-0.000
360.000	0.103	0.015	0.002	0.000	-0.000
390.000	0.302	0.046	0.007	0.001	-0.000
420.000	0.813	0.137	0.021	0.003	0.001
450.000	2.005	0.372	0.062	0.010	0.001
480.000	4.538	0.934	0.170	0.028	0.004
510.000	9.427	2.169	0.435	0.078	0.013
540.000	17.989	4.657	1.031	0.202	0.036
570.000	31.539	9.249	2.276	0.488	0.094
600.000	50.827	16.997	4.676	1.103	0.230
630.000	75.306	28.913	8.941	2.333	0.532
660.000	102.602	45.533	15.919	4.616	1.152
690.000	128.578	66.401	26.396	8.545	2.348
720.000	148.231	89.680	40.763	14.809	4.496
750.000	157.228	112.195	58.661	24.025	8.095
780.000	153.464	130.036	78.643	36.495	13.705
810.000	137.851	139.640	98.245	51.914	21.819
840.000	113.971	138.953	114.382	69.153	32.671
870.000	86.736	128.136	124.116	86.289	46.015
900.000	60.765	109.511	125.535	100.848	60.964

CONCENTRATION (PPM) AS A FUNCTION OF TIME AND DEPTH

DEPTH (CM)	TIME (DAYS)				
	160.0	170.0	180.0	190.0	200.0
30.000	-0.000	-0.000	-0.000	-0.000	-0.000
60.000	-0.000	-0.000	-0.000	-0.000	-0.000
90.000	-0.000	-0.000	-0.000	-0.000	-0.000
120.000	-0.000	-0.000	-0.000	-0.000	-0.000
150.000	-0.000	-0.000	-0.000	-0.000	-0.000
180.000	-0.000	-0.000	-0.000	-0.000	-0.000
210.000	-0.000	-0.000	-0.000	-0.000	-0.000
240.000	-0.000	-0.000	-0.000	-0.000	-0.000
270.000	-0.000	-0.000	-0.000	-0.000	-0.000
300.000	-0.000	-0.000	-0.000	-0.000	-0.000
330.000	-0.000	-0.000	-0.000	-0.000	-0.000
360.000	-0.000	-0.000	-0.000	-0.000	-0.000
390.000	-0.000	-0.000	-0.000	-0.000	-0.000
420.000	-0.000	-0.000	-0.000	-0.000	-0.000
450.000	0.000	-0.000	-0.000	-0.000	-0.000
480.000	0.001	-0.000	-0.000	-0.000	-0.000
510.000	0.002	0.001	-0.000	-0.000	-0.000
540.000	0.006	0.001	-0.000	-0.000	-0.000
570.000	0.017	0.003	0.001	-0.000	-0.000
600.000	0.044	0.008	0.001	0.000	-0.000
630.000	0.109	0.020	0.004	0.001	0.001
660.000	0.255	0.051	0.009	0.002	0.001
690.000	0.565	0.122	0.024	0.004	0.002
720.000	1.180	0.275	0.058	0.011	0.005
750.000	2.328	0.588	0.133	0.028	0.013
780.000	4.334	1.190	0.290	0.064	0.031
810.000	7.616	2.281	0.602	0.143	0.070
840.000	12.633	4.142	1.184	0.301	0.150
870.000	19.784	7.124	2.214	0.607	0.308
900.000	29.253	11.607	3.931	1.165	

CONCENTRATION(PPM) AS A FUNCTION OF TIME AND DEPTH

DEPTH(CM)	TIME(DAYS)				
	210.0	220.0	230.0	240.0	250.0
30.000	-0.000	-0.000	-0.000	-0.000	-0.000
60.000	-0.000	-0.000	-0.000	-0.000	-0.000
90.000	-0.000	-0.000	-0.000	-0.000	-0.000
120.000	-0.000	-0.000	-0.000	-0.000	-0.000
150.000	-0.000	-0.000	-0.000	-0.000	-0.000
180.000	-0.000	-0.000	-0.000	-0.000	-0.000
210.000	-0.000	-0.000	-0.000	-0.000	-0.000
240.000	-0.000	-0.000	-0.000	-0.000	-0.000
270.000	-0.000	-0.000	-0.000	-0.000	-0.000
300.000	-0.000	-0.000	-0.000	-0.000	-0.000
330.000	-0.000	-0.000	-0.000	-0.000	-0.000
360.000	-0.000	-0.000	-0.000	-0.000	-0.000
390.000	-0.000	-0.000	-0.000	-0.000	-0.000
420.000	-0.000	-0.000	-0.000	-0.000	-0.000
450.000	-0.000	-0.000	-0.000	-0.000	-0.000
480.000	-0.000	-0.000	-0.000	-0.000	-0.000
510.000	-0.000	-0.000	-0.000	-0.000	-0.000
540.000	-0.000	-0.000	-0.000	-0.000	-0.000
570.000	-0.000	-0.000	-0.000	-0.000	-0.000
600.000	-0.000	-0.000	-0.000	-0.000	-0.000
630.000	-0.000	-0.000	-0.000	-0.000	-0.000
660.000	-0.000	-0.000	-0.000	-0.000	-0.000
690.000	0.000	-0.000	-0.000	-0.000	-0.000
720.000	0.000	-0.000	-0.000	-0.000	-0.000
750.000	0.001	0.000	-0.000	-0.000	-0.000
780.000	0.002	0.000	-0.000	-0.000	-0.000
810.000	0.006	0.001	0.000	-0.000	-0.000
840.000	0.015	0.003	0.001	0.000	-0.000
870.000	0.034	0.007	0.001	0.000	-0.000
900.000	0.074	0.016	0.003	0.001	0.000

CONCENTRATION(PPM) AS A FUNCTION OF TIME AND DEPTH

DEPTH(CM)	TIME(DAYS)				
	260.0	270.0	280.0	290.0	300.0
30.000	-0.000	-0.000	-0.000	-0.000	-0.000
60.000	-0.000	-0.000	-0.000	-0.000	-0.000
90.000	-0.000	-0.000	-0.000	-0.000	-0.000
120.000	-0.000	-0.000	-0.000	-0.000	-0.000
150.000	-0.000	-0.000	-0.000	-0.000	-0.000
180.000	-0.000	-0.000	-0.000	-0.000	-0.000
210.000	-0.000	-0.000	-0.000	-0.000	-0.000
240.000	-0.000	-0.000	-0.000	-0.000	-0.000
270.000	-0.000	-0.000	-0.000	-0.000	-0.000
300.000	-0.000	-0.000	-0.000	-0.000	-0.000
330.000	-0.000	-0.000	-0.000	-0.000	-0.000
360.000	-0.000	-0.000	-0.000	-0.000	-0.000
390.000	-0.000	-0.000	-0.000	-0.000	-0.000
420.000	-0.000	-0.000	-0.000	-0.000	-0.000
450.000	-0.000	-0.000	-0.000	-0.000	-0.000
480.000	-0.000	-0.000	-0.000	-0.000	-0.000
510.000	-0.000	-0.000	-0.000	-0.000	-0.000
540.000	-0.000	-0.000	-0.000	-0.000	-0.000
570.000	-0.000	-0.000	-0.000	-0.000	-0.000
600.000	-0.000	-0.000	-0.000	-0.000	-0.000
630.000	-0.000	-0.000	-0.000	-0.000	-0.000
660.000	-0.000	-0.000	-0.000	-0.000	-0.000
690.000	-0.000	-0.000	-0.000	-0.000	-0.000
720.000	-0.000	-0.000	-0.000	-0.000	-0.000
750.000	-0.000	-0.000	-0.000	-0.000	-0.000
780.000	-0.000	-0.000	-0.000	-0.000	-0.000
810.000	-0.000	-0.000	-0.000	-0.000	-0.000
840.000	-0.000	-0.000	-0.000	-0.000	-0.000
870.000	-0.000	-0.000	-0.000	-0.000	-0.000
900.000	-0.000	-0.000	-0.000	-0.000	-0.000

CONCENTRATION (PPM) AS A FUNCTION OF TIME AND DEPTH

DEPTH (CM)	TIME (DAYS)				
	310.0	320.0	330.0	340.0	350.0
30.000	-0.000	-0.000	-0.000	-0.000	-0.000
60.000	-0.000	-0.000	-0.000	-0.000	-0.000
90.000	-0.000	-0.000	-0.000	-0.000	-0.000
120.000	-0.000	-0.000	-0.000	-0.000	-0.000
150.000	-0.000	-0.000	-0.000	-0.000	-0.000
180.000	-0.000	-0.000	-0.000	-0.000	-0.000
210.000	-0.000	-0.000	-0.000	-0.000	-0.000
240.000	-0.000	-0.000	-0.000	-0.000	-0.000
270.000	-0.000	-0.000	-0.000	-0.000	-0.000
300.000	-0.000	-0.000	-0.000	-0.000	-0.000
330.000	-0.000	-0.000	-0.000	-0.000	-0.000
360.000	-0.000	-0.000	-0.000	-0.000	-0.000
390.000	-0.000	-0.000	-0.000	-0.000	-0.000
420.000	-0.000	-0.000	-0.000	-0.000	-0.000
450.000	-0.000	-0.000	-0.000	-0.000	-0.000
480.000	-0.000	-0.000	-0.000	-0.000	-0.000
510.000	-0.000	-0.000	-0.000	-0.000	-0.000
540.000	-0.000	-0.000	-0.000	-0.000	-0.000
570.000	-0.000	-0.000	-0.000	-0.000	-0.000
600.000	-0.000	-0.000	-0.000	-0.000	-0.000
630.000	-0.000	-0.000	-0.000	-0.000	-0.000
660.000	-0.000	-0.000	-0.000	-0.000	-0.000
690.000	-0.000	-0.000	-0.000	-0.000	-0.000
720.000	-0.000	-0.000	-0.000	-0.000	-0.000
750.000	-0.000	-0.000	-0.000	-0.000	-0.000
780.000	-0.000	-0.000	-0.000	-0.000	-0.000
810.000	-0.000	-0.000	-0.000	-0.000	-0.000
840.000	-0.000	-0.000	-0.000	-0.000	-0.000
870.000	-0.000	-0.000	-0.000	-0.000	-0.000
900.000	-0.000	-0.000	-0.000	-0.000	-0.000

CONCENTRATION(PPM) AS A FUNCTION OF TIME AND DEPTH

DEPTH(CM)	TIME(DAYS)				
	360.0	0.0	0.0	0.0	0.0
30.000	-0.000	0.000	0.000	0.000	0.000
60.000	-0.000	0.000	0.000	0.000	0.000
90.000	-0.000	0.000	0.000	0.000	0.000
120.000	-0.000	0.000	0.000	0.000	0.000
150.000	-0.000	0.000	0.000	0.000	0.000
180.000	-0.000	0.000	0.000	0.000	0.000
210.000	-0.000	0.000	0.000	0.000	0.000
240.000	-0.000	0.000	0.000	0.000	0.000
270.000	-0.000	0.000	0.000	0.000	0.000
300.000	-0.000	0.000	0.000	0.000	0.000
330.000	-0.000	0.000	0.000	0.000	0.000
360.000	-0.000	0.000	0.000	0.000	0.000
390.000	-0.000	0.000	0.000	0.000	0.000
420.000	-0.000	0.000	0.000	0.000	0.000
450.000	-0.000	0.000	0.000	0.000	0.000
480.000	-0.000	0.000	0.000	0.000	0.000
510.000	-0.000	0.000	0.000	0.000	0.000
540.000	-0.000	0.000	0.000	0.000	0.000
570.000	-0.000	0.000	0.000	0.000	0.000
600.000	-0.000	0.000	0.000	0.000	0.000
630.000	-0.000	0.000	0.000	0.000	0.000
660.000	-0.000	0.000	0.000	0.000	0.000
690.000	-0.000	0.000	0.000	0.000	0.000
720.000	-0.000	0.000	0.000	0.000	0.000
750.000	-0.000	0.000	0.000	0.000	0.000
780.000	-0.000	0.000	0.000	0.000	0.000
810.000	-0.000	0.000	0.000	0.000	0.000
840.000	-0.000	0.000	0.000	0.000	0.000
870.000	-0.000	0.000	0.000	0.000	0.000
900.000	-0.000	0.000	0.000	0.000	0.000

FLUX (MICROGRAMS/CM*CM/DAY) AND LOSS (PERCENT)
AS A FUNCTION OF TIME

TIME(DAYS)	FLUX	LOSS
10.0	-29.498	% 3301.1881D+40
20.0	-1.116	% 3499.7800D+39
30.0	-0.061	% 3272.7889D+38
40.0	-0.003	% 3034.5398D+37
50.0	0.001	% 2818.9946D+36
60.0	-0.001	% 2631.1849D+35
70.0	-0.000	% 2468.0003D+34
80.0	-0.000	% 2325.3351D+33
90.0	-0.000	% 2199.5582D+32
100.0	-0.000	% 2087.7225D+31
110.0	-0.000	% 1987.4882D+30
120.0	-0.000	% 1897.0004D+29
130.0	-0.000	% 1814.7805D+28
140.0	-0.000	% 1739.6391D+27
150.0	-0.000	% 1670.6100D+26
160.0	-0.000	% 1606.9010D+25
170.0	-0.000	% 1547.8562D+24
180.0	-0.000	% 1492.9277D+23
190.0	-0.000	% 1441.6542D+22
200.0	-0.000	% 1393.6440D+21
210.0	-0.000	% 1348.5627D+20
220.0	-0.000	% 1306.1222D+19
230.0	-0.000	% 1266.0732D+18
240.0	-0.000	% 1228.1987D+17
250.0	-0.000	% 1192.3088D+16
260.0	-0.000	% 1158.2362D+15
270.0	-0.000	% 1125.8334D+14
280.0	-0.000	% 1094.9692D+13
290.0	-0.000	% 1065.5268D+12
300.0	-0.000	% 1037.4018D+11
310.0	-0.000	% 1010.5002D+10
320.0	-0.000	% 9847.3761D+08
330.0	-0.000	% 9600.3762D+06
340.0	-0.000	% 9363.3104D+04
350.0	-0.000	%913554950.2806
360.0	-0.000	%89165210.9583

CAUTION: THE USE OF TOO LARGE TIME STEPS MAY CAUSE THE ESTIMATED CUMULATIVE VOLATILIZATION LOSSES TO BE ERRONEOUS. USE THE ESTIMATED TOTAL LOSSES AT INFINITE TIME AS FOLLOWS.

THE TOTAL FRACTION VOLATILIZED IS APPROXIMATELY 0.8420
ASSUMING ZERO WATER EVAPORATION AND LARGE KH (SEE JURY APP. B)

Ignore vapor phase, assume equilibrium at water table

$7 \text{ ppm} = 15 \text{ g/m}^3$
 $15 \text{ g/m}^3 = \frac{15 \text{ g}}{\text{m}^3} = \frac{15 \text{ g}}{\text{L}}$

$$C_T = \theta C_w + K_{oc} f_{oc} P_c C_w$$

$$C_w = \frac{C_T}{\theta + K_{oc} f_{oc} P_c} = \frac{C_T}{0.3 + 45(1.002)(1.86)} = \frac{C_T}{0.32}$$

Total mass entering GW from day 70 to 230 [dt = 10d]

$$M = \sum_{i=1}^{16} \frac{(C_i + C_{i+1})}{2(0.32)} (10Q) = \frac{5Q}{.32} \sum_{i=1}^{16} (C_{i+1} + C_i)$$

where $Q = A \times R = 9 \text{ ft}^2 (.125 \text{ cm/d}) = 1045 \text{ cm}^3/\text{d}$
 $= 1.045 \text{ L/d}$

$$M = \frac{5Q}{.32} \left\{ C_1 + 2 \sum_{i=2}^{15} C_i + C_{16} \right\} = 16.33 \left\{ .002 + .003 + \dots + .003 \right\}$$

1050.998

$$= 17162 \text{ mg} = 17.2 \text{ g} = \underline{\underline{0.0172 \text{ Kg}}}$$

Only about 1% made it to the water table!

Assume for worst case that this actually enters the aquifer as a slug.

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*      INTERNATIONAL GROUND WATER MODELING CENTER      *
*      Indianapolis, USA - Delft, The Netherlands      *
*
*      S O L U T E   version 2.00                      *
*
*      ANALYTICAL MODELS FOR SOLUTE TRANSPORT          *
*
*****
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PROJECT..... = SUFFOLK ANG/FTA
USER NAME..... = H. ANDOLSEK
DATE..... = 03-30-1993
DATA FILE..... =

INPUT DATA:

GROUNDWATER (SEEPAGE) VELOCITY.... = .76 [ft/d]
POROSITY..... = .3
LONGITUDINAL DISPERSIVITY..... = 10 [ft]
LATERAL DISPERSIVITY..... = 1 [ft]
VERTICAL DISPERSIVITY..... = .1 [ft]
HALF-LIFE..... = 0 [d]
NUMBER OF POINT SOURCES..... = 1

SOURCE NO. 1

X-COORDINATE OF THE SOURCE..... = 0 [ft]
Y-COORDINATE OF THE SOURCE..... = 0 [ft]
Z-COORDINATE OF THE SOURCE..... = 0 [ft]
TOTAL SOLUTE MASS INJECTED..... = .038 [lb]
ELAPSED TIME..... = 548 [d]

GRID DATA:

X-COORDINATE OF GRID ORIGIN..... = 0 [ft]
Y-COORDINATE OF GRID ORIGIN..... = 0 [ft]
Z-COORDINATE OF GRID ORIGIN..... = 0 [ft]
DISTANCE INCREMENT DELX..... = 25 [ft]
DISTANCE INCREMENT DELY..... = 10 [ft]
DISTANCE INCREMENT DELZ..... = 1 [ft]
NUMBER OF NODES IN X-DIRECTION.... = 20
NUMBER OF NODES IN Y-DIRECTION.... = 10
NUMBER OF NODES IN Z-DIRECTION.... = 1

CONCENTRATION C [mg/l] - LAYER 1

ROW\COLUMN			1	2	3	4	5
[ft]			0.00	25.00	50.00	75.00	100.00
1	0.00	[ft]	-0.0000	0.0000	0.0000	0.0000	0.0000
2	10.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
3	20.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
4	30.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
5	40.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
6	50.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
7	60.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
8	70.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
9	80.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
10	90.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000

ROW\COLUMN			6	7	8	9	10
		[ft]	125.00	150.00	175.00	200.00	225.00
1	0.00	[ft]	0.0000	0.0001	0.0002	0.0003	0.0006
2	10.00	[ft]	0.0000	0.0001	0.0002	0.0003	0.0006
3	20.00	[ft]	0.0000	0.0001	0.0001	0.0003	0.0005
4	30.00	[ft]	0.0000	0.0000	0.0001	0.0002	0.0003
5	40.00	[ft]	0.0000	0.0000	0.0001	0.0001	0.0002
6	50.00	[ft]	0.0000	0.0000	0.0000	0.0001	0.0001
7	60.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0001
8	70.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
9	80.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
10	90.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000

ROW\COLUMN			11	12	13	14	15
		[ft]	250.00	275.00	300.00	325.00	350.00
1	0.00	[ft]	0.0010	0.0016	0.0024	0.0032	0.0041
2	10.00	[ft]	0.0010	0.0015	0.0022	0.0031	0.0039
3	20.00	[ft]	0.0008	0.0013	0.0019	0.0026	0.0032
4	30.00	[ft]	0.0006	0.0009	0.0014	0.0019	0.0024
5	40.00	[ft]	0.0004	0.0006	0.0009	0.0012	0.0016
6	50.00	[ft]	0.0002	0.0004	0.0005	0.0007	0.0009
7	60.00	[ft]	0.0001	0.0002	0.0003	0.0004	0.0005
8	70.00	[ft]	0.0001	0.0001	0.0001	0.0002	0.0002
9	80.00	[ft]	0.0000	0.0000	0.0001	0.0001	0.0001
10	90.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000

ROW\COLUMN	16	17	18	19	20
[ft]	375.00	400.00	425.00	450.00	475.00

1	0.00 [ft]	0.0048	0.0053	0.0053	0.0050	0.0044
2	10.00 [ft]	0.0046	0.0050	0.0050	0.0047	0.0041
3	20.00 [ft]	0.0038	0.0041	0.0042	0.0039	0.0034
4	30.00 [ft]	0.0028	0.0031	0.0031	0.0029	0.0025
5	40.00 [ft]	0.0018	0.0020	0.0020	0.0019	0.0017
6	50.00 [ft]	0.0011	0.0012	0.0012	0.0011	0.0010
7	60.00 [ft]	0.0006	0.0006	0.0006	0.0006	0.0005
8	70.00 [ft]	0.0003	0.0003	0.0003	0.0003	0.0002
9	80.00 [ft]	0.0001	0.0001	0.0001	0.0001	0.0001
10	90.00 [ft]	0.0000	0.0000	0.0000	0.0000	0.0000

*
* INTERNATIONAL GROUND WATER MODELING CENTER *
* Indianapolis, USA - Delft, The Netherlands *
*
* S O L U T E version 2.00 *
*
* ANALYTICAL MODELS FOR SOLUTE TRANSPORT *
*

PROJECT..... = Suffolk Cty ANG
USER NAME..... = R. Lewis
DATE..... = 02-08-1993
DATA FILE..... =

INPUT DATA:

GROUNDWATER (SEEPAGE) VELOCITY.... = .76 [ft/d]
POROSITY..... = .3
LONGITUDINAL DISPERSIVITY..... = 10 [ft]
LATERAL DISPERSIVITY..... = 1 [ft]
VERTICAL DISPERSIVITY..... = .1 [ft]
HALF-LIFE..... = 0 [d]
NUMBER OF POINT SOURCES..... = 1

SOURCE NO. 1

X-COORDINATE OF THE SOURCE..... = 0 [ft]
Y-COORDINATE OF THE SOURCE..... = 0 [ft]
Z-COORDINATE OF THE SOURCE..... = 0 [ft]
TOTAL SOLUTE MASS INJECTED..... = 17.1 [lb]
ELAPSED TIME..... = 5263 [d]

GRID DATA:

X-COORDINATE OF GRID ORIGIN..... = 0 [ft]
Y-COORDINATE OF GRID ORIGIN..... = 0 [ft]
Z-COORDINATE OF GRID ORIGIN..... = 0 [ft]
DISTANCE INCREMENT DELX..... = 200 [ft]
DISTANCE INCREMENT DELY..... = 10 [ft]
DISTANCE INCREMENT DELZ..... = 1 [ft]
NUMBER OF NODES IN X-DIRECTION.... = 21
NUMBER OF NODES IN Y-DIRECTION.... = 10
NUMBER OF NODES IN Z-DIRECTION.... = 1

CONCENTRATION C [mg/l] - LAYER 1

ROW\COLUMN			1	2	3	4	5
[ft]			0.00	200.00	400.00	600.00	800.00
1	0.00	[ft]	-0.0000	0.0000	0.0000	0.0000	0.0000
2	10.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
3	20.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
4	30.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
5	40.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
6	50.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
7	60.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
8	70.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
9	80.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
10	90.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000

ROW\COLUMN			6	7	8	9	10
[ft]			1000.00	1200.00	1400.00	1600.00	1800.00
1	0.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
2	10.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
3	20.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
4	30.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
5	40.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
6	50.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
7	60.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
8	70.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
9	80.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
10	90.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000

ROW\COLUMN			11	12	13	14	15
[ft]			2000.00	2200.00	2400.00	2600.00	2800.00
1	0.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
2	10.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
3	20.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
4	30.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
5	40.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
6	50.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
7	60.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
8	70.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
9	80.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000
10	90.00	[ft]	0.0000	0.0000	0.0000	0.0000	0.0000

ROW\COLUMN			16	17	18	19	20
		[ft]	3000.00	3200.00	3400.00	3600.00	3800.00
1	0.00	[ft]	0.0002	0.0015	0.0085	0.0298	0.0631
2	10.00	[ft]	0.0002	0.0015	0.0085	0.0296	0.0627
3	20.00	[ft]	0.0002	0.0014	0.0083	0.0291	0.0616
4	30.00	[ft]	0.0001	0.0014	0.0081	0.0282	0.0597
5	40.00	[ft]	0.0001	0.0013	0.0077	0.0270	0.0571
6	50.00	[ft]	0.0001	0.0013	0.0073	0.0255	0.0540
7	60.00	[ft]	0.0001	0.0012	0.0068	0.0238	0.0504
8	70.00	[ft]	0.0001	0.0011	0.0063	0.0220	0.0465
9	80.00	[ft]	0.0001	0.0010	0.0057	0.0200	0.0423
10	90.00	[ft]	0.0001	0.0009	0.0052	0.0180	0.0380

ROW\COLUMN		21
	[ft]	4000.00
1	0.00 [ft]	0.0810
2	10.00 [ft]	0.0805
3	20.00 [ft]	0.0790
4	30.00 [ft]	0.0766
5	40.00 [ft]	0.0733
6	50.00 [ft]	0.0693
7	60.00 [ft]	0.0647
8	70.00 [ft]	0.0596
9	80.00 [ft]	0.0543
10	90.00 [ft]	0.0488

ATTACHMENT N

Evaluation of Volatilization by Organic Chemicals Residing Below the Soil Surface

WILLIAM A. JURY,¹ DAVID RUSSO,² GARY STREILE,³ AND HESHAM EL ABD⁴

Although volatile organic compounds located in buried waste repositories or distributed through the unsaturated soil zone have the potential to migrate to the atmosphere by vapor diffusion, little attention has been paid in the past to estimating the importance of volatilization losses. In this paper a screening model is introduced which evaluates the relative volatilization losses of a number of organic compounds under standard soil conditions. The model is an analytic solution to the problem wherein the organic chemical is located at time zero at uniform concentration in a finite layer of soil covered by a layer of soil devoid of chemical. The compound is assumed to move by vapor or liquid diffusion and by mass flow under the influence of steady upward or zero water flow while undergoing first-order degradation and linear equilibrium adsorption. Loss to the atmosphere is governed by vapor diffusion through a stagnant air boundary layer. Calculations are performed on 35 organic compounds in two model soils with properties characteristic of sandy and clayey soil. The model identifies those compounds with high potential for loss during 1 year after incorporation under 100 cm of soil cover and also is used to calculate the minimum soil cover thickness required to reduce volatilization losses to insignificant levels during the lifetime of the compound in the soil. From the latter calculation it was determined that certain compounds may volatilize from deep subsurface locations or even groundwater unless the soil surface is sealed to prevent gas migration.

INTRODUCTION

Volatile organic chemicals may enter the soil from a variety of sources. They may be deliberately confined in waste repositories or landfills that are covered with a layer of soil. They may inadvertently enter the vadose zone from a surface spill or a leaking storage tank, which places at least part of the chemical spill below the ground. Once these chemicals are introduced into the vadose zone, they may ultimately migrate to the groundwater and may be present either as a dissolved constituent or as part of an immiscible fluid such as gasoline which floats on top of the groundwater table. Some of these contaminated locations may contain considerable chemical mass, which can potentially volatilize for years.

Although at one time little concern was raised over volatile emissions of potentially hazardous organic chemicals from soil, this is no longer the case. Abandoned waste repositories such as the Stringfellow Acid Pits in California have been covered with clay caps to prevent escape of volatile compounds to the atmosphere [Ember, 1985]. Concentrated pesticide residues have been detected in atmospheric aerosols above farmland in California and in Maryland [Glutfelty *et al.*, 1987].

Many of the volatile organic chemicals found in groundwater and in landfills have been found to have adverse health effects in toxicology studies. For example, benzene, a common constituent of U.S. groundwaters, has been identified as a human carcinogen by the National Institute for Occupational Safety and Health [Office of Technology Assessment, 1987]. Much attention has been focused on the potential exposure of

humans via drinking water to trichloroethylene (TCE) a common industrial solvent widely found in groundwater, and this attention has led to substantial numbers of wells being closed down when high TCE levels are observed. However, the extent of and health implications of long-term exposure from volatile emissions of organic chemicals in groundwater or buried soil repositories are poorly understood at present [Andelman and Underhill, 1987].

The purpose of this paper is to describe a chemical transport and reaction model that may be used to evaluate the extent of volatilization to the atmosphere from organic compounds that are located below the soil surface. Because the model is based on a number of simplifying assumptions, it is not intended to be used to simulate volatilization at a specific site. Rather, it has been designed as a screening model to assess the volatilization potential of a large number of compounds under standard soil and environmental conditions. By comparing the behavior of different compounds in identical settings, chemicals with significant potential for volatilization may be identified. Moreover, compounds may be grouped into similar behavior classes so that chemicals for which there is no experimental information may be linked to compounds which have been monitored under natural conditions.

THEORY

The mathematical model used to make the calculations presented in this paper is derived by a transformation of the behavior assessment screening model published by Jury *et al.* [1983], which is based on the following assumptions:

1. Chemicals may reside in three phases in the soil: an adsorbed phase, whose concentration C_s is expressed in micrograms per gram of soil; a dissolved phase, whose concentration C_l is expressed in micrograms per cubic centimeter of soil solution; and a gaseous phase, whose concentration C_g is expressed in micrograms per cubic centimeter of soil air. The total concentration C_T in micrograms per cubic centimeter of soil is thus

$$C_T = \rho_b C_s + \theta C_l + \alpha C_g \quad (1)$$

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where ρ_b (g cm^{-3}) is soil bulk density, θ is volumetric water content, and a is volumetric air content.

2. The chemical flux J_x ($\mu\text{g cm}^{-2} \text{d}^{-1}$) is the sum of the vapor flux J_v and the flux of dissolved solute J_l . The vapor flux J_v is given by the modified form of Fick's law of diffusion:

$$J_x = -D_x \partial C_x / \partial z = -\xi_x D_x^a \partial C_x / \partial z \quad (2)$$

where D_x and D_x^a ($\text{cm}^2 \text{d}^{-1}$) are the gaseous diffusion coefficients in soil and air, respectively, and ξ_x is a factor accounting for vapor diffusion porosity and tortuosity effects. The flux of dissolved solute J_l is expressed as the sum of the liquid diffusion flux and the convective flux:

$$J_l = -D_l \partial C_l / \partial z - J_w C_l = -\xi_l D_l^a \partial C_l / \partial z + J_w C_l \quad (3)$$

where J_w (cm d^{-1}) is the volumetric soil water flux, D_l and D_l^a ($\text{cm}^2 \text{d}^{-1}$) are the liquid diffusion coefficients in soil and pure water, respectively, and ξ_l is a factor accounting for liquid diffusion porosity and tortuosity effects.

3. The vapor phase and liquid phase porosity and tortuosity factors are assumed to obey the model of Millington and Quirk [1961]

$$\xi_g = a^{103} / \phi^2 \quad (4a)$$

$$\xi_l = \theta^{103} / \phi^2 \quad (4b)$$

where $\phi = \theta a + \theta$ is total soil porosity.

4. The chemical is assumed to undergo first-order biological/chemical degradation in the soil with a rate constant μ (d^{-1}) that is related to the effective half-life τ (days) by

$$\mu = \ln(2) / \tau \quad (5)$$

5. The chemical moves in one dimension through the soil in accordance with the principle of mass balance:

$$\partial C_T / \partial t + \partial J_x / \partial z + \mu C_T = 0 \quad (6)$$

6. The adsorbed and dissolved phases are assumed to undergo reversible, linear equilibrium adsorption, as expressed by

$$C_s = K_d C_l = f_{oc} K_{oc} C_l \quad (7)$$

where K_d ($\text{cm}^3 \text{g}^{-1}$) is the distribution coefficient, f_{oc} is the soil organic carbon fraction, and K_{oc} ($\text{cm}^3 \text{g}^{-1}$) is the organic carbon partition coefficient.

7. The dissolved and gaseous phases are assumed to be in equilibrium in accordance with a modified Henry's law:

$$C_g = K_H C_l \quad (8)$$

where K_H is the dimensionless form of Henry's constant.

8. The soil properties, a , θ , ϕ , ρ , and f_{oc} are assumed to be constant in space and time, as is the temperature.

9. Water flux J_w is constant in space and time (upward, downward, or zero).

10. Volatilization of chemical vapor to the atmosphere is assumed to occur by vapor diffusion through a stagnant air boundary layer of thickness d (cm), above which the chemical concentration is zero. Thus the upper boundary condition at the soil surface ($z = 0$) is

$$J_x(o, t) = -D_x^a C_g(o, t) / d = -h C_g(o, t) \quad (9)$$

where $h = D_x^a / d$ (cm d^{-1}) is the boundary layer transfer coefficient. Jury *et al.* [1983] discuss ways of estimating values of d . The minus sign is required in (9) because the z direction is positive downward.

Under these assumptions the transport equation derived from the flux equations (2)–(3) and the mass balance equation (6) may be simplified to [Jury *et al.*, 1983]

$$\frac{\partial C_T}{\partial t} + \mu C_T = D_E \frac{\partial^2 C_T}{\partial z^2} - V_E \frac{\partial C_T}{\partial z} \quad (10)$$

where

$$V_E = J_w / (\rho_b f_{oc} K_{oc} + \theta + a K_H) \quad (11)$$

is the effective solute velocity, and

$$D_E = [(a^{103} D_g^a K_H + \theta^{103} D_l^a) / \phi^2] / (\rho_b f_{oc} K_{oc} + \theta + a K_H) \quad (12)$$

is the effective diffusion coefficient.

In this notation the upper boundary condition may be rewritten in terms of total concentration as

$$-D_E \partial C_T / \partial z + V_E C_T = -H_E C_T \quad \text{at } z = 0 \quad (13)$$

where

$$H_E = h K_H / (\rho_b f_{oc} K_{oc} + \theta + a K_H) \quad (14)$$

Jury *et al.* [1983] solved (10) with the upper boundary condition (13) for the case of a chemical initially incorporated to depth L at a uniform concentration C_o .

$$\begin{aligned} C_T(z, 0) &= C_o & 0 < z < L \\ C_T(z, 0) &= 0 & z > L \end{aligned} \quad (15)$$

and the lower boundary condition

$$C_T(\infty, t) = 0 \quad (16)$$

The solutions for the concentration and the flux at the soil surface [Jury *et al.*, 1983, equations 24 and 25] are

$$\begin{aligned} C_T(z, t; L) &= \frac{1}{2} C_o \exp(-\mu t) \left\{ \operatorname{erfc} \left[\frac{(z - L - V_E t)}{(4 D_E t)^{1/2}} \right] \right. \\ &\quad - \operatorname{erfc} \left[\frac{(z - V_E t)}{(4 D_E t)^{1/2}} \right] + (1 + V_E / H_E) \\ &\quad \cdot \exp(V_E z / D_E) \left[\operatorname{erfc} \left(\frac{(z + L + V_E t)}{(4 D_E t)^{1/2}} \right) \right. \\ &\quad - \operatorname{erfc} \left(\frac{(z + V_E t)}{(4 D_E t)^{1/2}} \right) \left. \right] + (2 + V_E / H_E) \\ &\quad \cdot \exp([H_E(H_E + V_E)t + (H_E + V_E)z] / D_E) \\ &\quad \left. \left[\operatorname{erfc} \left(\frac{[z + (2 H_E + V_E)t]}{(4 D_E t)^{1/2}} \right) \right] \right. \\ &\quad \left. - \exp(H_E L / D_E) \operatorname{erfc} \left(\frac{[z + L + (2 H_E + V_E)t]}{(4 D_E t)^{1/2}} \right) \right\} \quad (17) \end{aligned}$$

TABLE 1. Chemodynamic Fate Properties of Volatile Organic Compounds Used in the Simulations

Compound	K_H	K_{ow} $\text{cm}^3 \text{g}^{-1}$	$t_{1/2}$ days
Acrolein	0.337E-01	0.100E-01	0.300E-03
Benzene	0.220E-01	0.800E-02	0.365E-03
Benzo B Fluoranthene	0.690E-02	0.480E-07	0.100E-03
Bromoethane	0.820E-01	0.900E-01	0.300E-02
Chlordane	0.100E-03	0.480E+03	0.100E-03
Chloroethane	0.615E-00	0.250E-02	0.300E-02
Chloroethene	0.152E+03	0.300E-01	0.300E-02
Chloroform	0.120E+00	0.290E-02	0.100E-03
Chloromethane	0.162E+01	0.600E-01	0.120E-03
2-Chloronaphthalene	0.220E-01	0.115E+04	0.144E-04
1,2-Dibromo-3-chloropropane (DBCP)	0.400E-03	0.129E+03	0.100E-04
Dichlorodifluoromethane	0.109E-03	0.111E+03	0.100E-05
1,1-Dichloroethane	0.177E+00	0.460E+02	0.450E-02
1,2-Dichloroethane	0.380E-01	0.220E-02	0.900E-02
Dichloromethane	0.128E+00	0.130E-02	0.100E-03
2,4-Dichlorophenol	0.200E-03	0.447E+03	0.160E-03
s-ethyl dipropylthiocarbonate (EPTC)	0.590E-03	0.280E-03	0.300E+02
Ethylene dibromide	0.350E-01	0.440E+02	0.365E-04
Heptachlor	0.341E+00	0.681E+04	0.220E+04
Hexachlorocyclohexane	0.300E-03	0.234E+04	0.725E+03
Methyl ethyl ketone	0.102E-02	0.100E+02	0.100E+03
Methyl isobutyl ketone	0.210E-02	0.220E+02	0.100E+03
Pentachlorophenol	0.100E-03	0.940E+05	0.100E+02
Phorate	0.310E-03	0.660E-03	0.820E+02
Pyrene	0.500E-03	0.197E+06	0.500E+03
Tetrachloro dibenzo-p-dioxin (TCDD)	0.320E-02	0.138E-07	0.365E+03
Toluene	0.280E+00	0.980E-02	0.500E-01
Toxaphene	0.125E+01	0.632E-03	0.365E-04
Triallate	0.790E-03	0.360E-04	0.100E+03
1,1,1-Trichloroethane	0.146E+01	0.113E-03	0.365E-03
Trichloroethylene	0.380E+00	0.138E+03	0.730E-03
Trichloromethane	0.120E+00	0.600E+02	0.500E-02
Xylene	0.940E+04	0.295E-03	0.110E-03

Read 0.337E+01 as 0.337×10^1 .

$$\begin{aligned}
 J_s(0, t; L) = & \frac{1}{2} C_0 \exp(-\mu t) \left\{ V_E \left[\operatorname{erfc} \left(\frac{V_E t}{(4D_E t)^{1/2}} \right) \right. \right. \\
 & \left. \left. - \operatorname{erfc} \left(\frac{(L + V_E t)}{(4D_E t)^{1/2}} \right) \right] + (2H_E + V_E) \right. \\
 & \cdot \exp[H_E(H_E + V_E)t/D_E] \left[\exp(H_E L/D_E) \right. \\
 & \cdot \operatorname{erfc} \left(\frac{[L + (2H_E + V_E)t]}{(4D_E t)^{1/2}} \right) \\
 & \left. \left. - \operatorname{erfc} \left(\frac{[(2H_E + V_E)t]}{(4D_E t)^{1/2}} \right) \right] \right\} \quad (18)
 \end{aligned}$$

The application of this behavior assessment model to assessing the volatility, persistence, and leaching of deposits of chemicals is illustrated by Jury *et al.* [1984a, b, c].

Because (10) and (13)–(15) are linear equations, the principle of superposition may be used to derive the solution to (10), (13), and (16) for the case of a chemical incorporated at uniform concentration in a finite buried layer of soil as represented by the initial condition

$$\begin{aligned}
 C_T(z, 0) &= 0 & 0 < z < L \\
 C_T(z, 0) &= C_0 & L < z < L + W \\
 C_T(z, 0) &= 0 & z > L + W
 \end{aligned} \quad (19)$$

where W is the thickness of the layer of incorporation of the chemical.

This solution is given by

$$C_T^b(z, t) = C_T(z, t; L + W) - C_T(z, t; L) \quad (20)$$

$$J_s^b(0, t) = J_s(0, t; L + W) - J_s(0, t; L) \quad (21)$$

where the superscript b denotes a solution to the buried chemical initial condition and $C_T(z, t; L + W)$ and $J_s(0, t; L + W)$ are the solutions (17) and (18), respectively, with $L \rightarrow L + W$. Equations (20) and (21) are used in all the calculations to follow. In addition, the cumulative mass volatilized from the soil during a specified time period is calculated with the equation given in Appendix A.

RESULTS

Table 1 summarizes the environmental fate or "chemodynamic" properties of 35 volatile organic compounds. The list in Table 2 was compiled from measured or estimated values given by Jury *et al.* [1984b], Rao *et al.* [1985], Wilkerson *et al.* [1984], and Ryan *et al.* [1988]. In cases where the values have been estimated crudely, such as for the 10-year half-life of ethylene dibromide [Rao *et al.*, 1985], the environmental fate properties may be significantly in error. Nonetheless, the half-life values, which are the most difficult to estimate, are probably accurate enough to provide a reasonable as-

TABLE 2. Standard Values of Soil and Chemical Properties Used in the Simulations

Property	Symbol	Sandy Soil	Clayey Soil	Units
Porosity	ϕ	0.4	0.5	...
Bulk density	ρ_b	1.59	1.32	g cm^{-3}
Water content	θ	0.18	0.375	...
Air content	α	0.22	0.125	...
Organic C fraction	f_{oc}	0.0075	0.025	...
Gaseous diffusion coefficient	D_g	4320	4320	$\text{cm}^2 \text{d}^{-1}$
Liquid diffusion coefficient	D_l	0.432	0.432	$\text{cm}^2 \text{d}^{-1}$
Boundary layer thickness	d	0.5	0.5	cm
Incorporated layer thickness	W	30	30	cm
Depth to incorporated layer	L	100	100	cm

assessment of the relative persistence of the compound in a biologically active surface zone of soil.

The screening model assessments of volatility from buried soil are run under ideal scenarios representing a soil with uniform porosity, bulk density, water content, and organic carbon fraction. In this study, two contrasting soil types will be used in the simulations, chosen to have properties characteristic of a relatively coarse-textured sandy soil and a finer-textured clayey soil. The standard values for the properties of these two soils are given in Table 2.

As an example of the effect of soil type on results of the screening simulations, Figure 1 shows a plot of the volatilization flux as a function of time (using (21)) and the final soil concentration as a function of depth (using (20)) for benzene during the first year after placement in a 30-cm-thick layer located 100 cm below the surface of a sandy and a clayey soil when water evaporation is negligible. In the sandy soil the benzene volatilization flux quickly rises to a maximum at about 30 days and remains high thereafter. In contrast, the flux from the clayey soil does not reach a maximum during

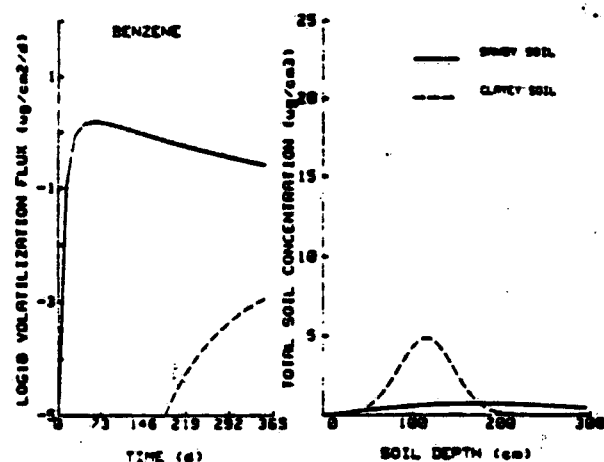


Fig. 1. Calculated volatilization flux and final soil concentration of benzene during 1 year after incorporation between 100 and 130 cm at a concentration of $25 \mu\text{g cm}^{-3}$.

TABLE 3. Cumulative Volatilization Losses of Chemicals During the First Year After Placement Below 1 m Expressed as a Percent of the Mass Initially Present Between 1.0 and 1.3 m

Compound	Sandy Soil	Clay Soil
Dichlorodifluoromethane	87.5	67.3
Acrolein	79.0	47.2
Xylene	72.5	45.2
Chloromethane	66.9	22.3
1,1,1-Trichloroethane	61.8	4.9
Chloroethene	54.2	22.1
Bromomethane	51.8	14.7
Toxaphene	41.5	...
Trichloroethylene	41.2	0.1
Benzene	34.3	0.01
Dichloromethane	29.7	0.2
Chloroethane	27.5	0.2
Chloroform	21.2	0.01
Ethylene dibromide	14.4	...
1,1-Dichloroethane	11.1	...
1,2-Dichloroethane	7.1	...
Trichloromethane	6.2	...
Toluene	0.1	...

No water evaporation.

the first year and is more than 2 orders of magnitude less than the flux from the sandy soil after 1 year. The final soil concentration of benzene is very diffuse after 1 year in the sandy soil but fairly narrow in the clayey soil. The calculated mass balances for the two cases after one year are 34.3% volatilized, 38.6% degraded, and 27.1% remaining in the sandy soil and 0.01% volatilized, 50% degraded, and 49.99% remaining in the clayey soil. Thus the sandy soil cover clearly provided inadequate resistance to volatilization into the atmosphere for this compound.

Screening for Relative Volatility (in the Absence of Water Evaporation)

The 35 compounds given in Table 1 have a wide range of chemodynamic properties. By running identical buried chemical screening tests on each compound, one is able to identify the relative order of volatility for the group of chemicals under the two contrasting soil regimes.

Table 3 summarizes the percent of the initial mass which has volatilized for each chemical during 1 year after incorporation between 100 and 130 cm, arranged from high to low volatility. Those compounds in Table 1 not listed in Table 3 had insignificant volatilization loss. The first seven compounds in Table 3 show significant losses in both the sandy soil and the clay soil, ranging from a high of nearly 90% for dichlorodifluoromethane in the sandy soil to a low of 4.9% for 1,1,1-trichloroethane in the clay soil. Except for these seven chemicals, all other compounds had insignificant volatilization during the first year in the clay soil. In contrast, 11 additional compounds manifested significant volatilization losses in the sandy soil during the first year of volatilization after placement. This strong dependence on soil conditions indicates how important the soil cover type is in regulating volatile losses to the atmosphere.

Effect of Soil Cover Thickness

Figures 2 and 3 show the percent of initial benzene mass incorporated in a 30-cm layer that has volatilized to the

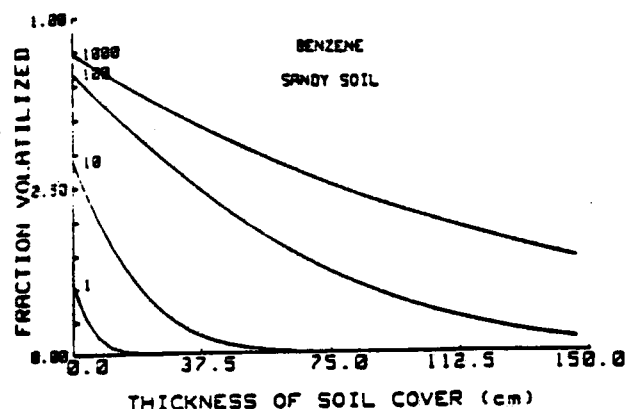


Fig. 2. Cumulative volatilization losses of benzene from sandy soil as a function of soil cover thickness and time (labeled in days), expressed as a fraction of the mass initially present in a 30-cm-thick layer (no water evaporation).

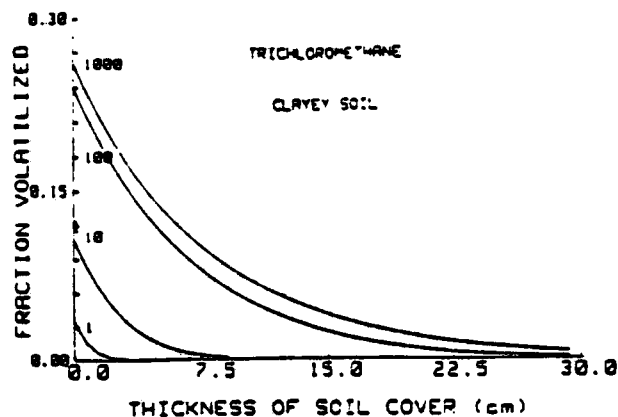


Fig. 4. Cumulative volatilization losses of trichloromethane from clayey soil as a function of soil cover thickness and time (labeled in days), expressed as a fraction of the mass initially present in a 30-cm-thick layer (no water evaporation).

atmosphere after varying time periods between 1 and 1000 days as a function of the thickness of the overlying soil cover in sandy and clayey soil, respectively. These two figures also illustrate both the differences between the extent of benzene loss by volatilization in the sandy and clayey soils in a given time period and the effect of increasing time on the cumulative loss of benzene vapor to the atmosphere. For example, after 100 days, very little benzene has escaped to the atmosphere of the sandy soil when buried below 150 cm. However, a 150-cm soil cover thickness does not restrict volatilization over 1000 days, and approximately 30% of the benzene initially present will escape to the atmosphere during this time period. In contrast, a compound like trichloromethane, which has a much shorter half-life than benzene, shows little difference in volatilization loss to the atmosphere after 100 and 1000 days (Figure 4), because it has degraded to a low concentration by 100 days. Thus for clayey soil cover thicknesses of greater than 30 cm, volatilization losses can essentially be eliminated for this chemical. This graph suggests that optimum soil covers may be designed for any volatile compound that degrades in soil by selecting layer thicknesses that create diffusive travel times

to the surface which are significantly in excess of the biological half-life of the compound in the soil.

Calculation of Limiting Cover Thickness

As shown in Appendix B, the fractional cumulative volatilization loss, by diffusion alone, of a compound covered by a thickness L of soil with uniform properties after an infinite time is given approximately by

$$V_c^b(\infty)/M_0 = \exp[-L(\mu/D_E)^{1/2}] \quad (22)$$

Thus for $L \gg (D_E/\mu)^{1/2}$, chemical volatilization losses to the atmosphere will be insignificant when water evaporation is not present. Table 4 summarizes values of cover thickness L calculated with (22) for the sandy and clayey soils under the restriction that mass losses by volatilization be held to less than 0.7% ($\exp(-5)$) during the lifetime of the chemical in the ground. Notable in this table are the enormous differences in cover thickness under the two conditions, ranging for a sandy soil from a low of 1 mm for pentachlorophenol and chrysene to a high of 166 m for dichlorodifluoromethane. Clearly, the latter compound cannot be restricted from volatilization losses to the atmosphere even when present in groundwater which resides a significant distance below the soil surface. In contrast, many of the reasonably volatile compounds such as benzene, bromomethane, etc., will volatilize significantly when covered by thin layers of soil but will probably not reach the atmosphere to any great extent when moving upward from deep groundwater tables, providing that biological degradation is not confined to shallow surface layers.

Effect of Water Evaporation

The previous scenarios have all assumed that the water phase is stagnant during the chemical vapor diffusion process. However, under certain conditions, such as when shallow water tables are present below soil surfaces that do not receive frequent water inputs, prolonged upward flow of water may occur. In such cases, compounds that are not significantly adsorbed and that have reasonable concentrations in the dissolved phase may have their volatilization losses enhanced when water flow is upward. Table 5 summarizes the percent volatilization losses during the first year

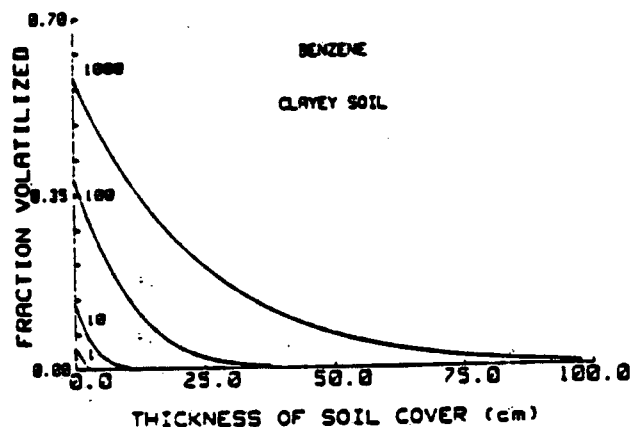


Fig. 3. Cumulative volatilization losses of benzene from clayey soil as a function of soil cover thickness and time (labeled in days), expressed as a fraction of the mass initially present in a 30-cm-thick layer (no water evaporation).

TABLE 4. Soil Cover Thickness (cm) Required to Restrict Volatilization to Less Than 0.7% of Mass Incorporated in Soil

Compound	Sandy Soil	Clayey Soil
Acrolein	2,555.0	864.9
Benzene	657.8	126.3
Benzo B Fluoranthene	0.3	0.1
Bromoethane	873.9	298.1
Chlordane	4.0	3.9
Chloroethane	444.3	94.4
Chloroethene	936.6	378.8
Chloroform	378.2	75.1
Chloromethane	1,445.5	392.4
Chrysene	0.1	0.0
1,2-dibromo-3-chloropropane (DBCP)	41.3	23.8
Dichlorodifluoromethane	16,645.8	6,150.0
1,1-Dichloroethane	261.2	51.0
1,2-Dichloroethane	223.8	45.7
Dichloromethane	482.2	99.3
2,4-Dichlorophenol	6.8	5.1
s-ethyl dipropylthiocarbamate (EPTC)	6.0	2.9
Ethylene dibromide	1,086.7	217.9
Heptachlor	245.7	45.4
Hexachlorocyclohexane	7.7	4.9
Methyl ethyl ketone	48.5	20.6
Methyl isobutyl ketone	56.5	18.2
Pentachlorophenol	0.1	0.1
Phorate	4.9	3.1
Pyrene	0.9	0.5
Tetrachlorodibenzo-p-dioxin	0.7	0.2
Toluene	80.7	15.4
Toxaphene	1,934.1	362.1
Triallate	3.6	1.5
1,1,1-Trichloroethane	1,373.9	276.4
Trichloroethylene	976.2	185.8
Trichloromethane	205.8	40.0
Xylene	1,797.4	731.2

after incorporation for chemicals that are placed 100 cm below the surface and are subjected to 0.1 cm d^{-1} of steady upward water flow. Comparison of Table 5 with Table 3 shows that certain compounds such as ethylene dibromide and 1,2-dichloroethane can increase their volatilization fluxes significantly under this condition. Similarly, other compounds, such as methyl ethyl ketone, that do not volatilize at all under stagnant water conditions may actually have some potential for migrating more rapidly to the surface when steady water flow is occurring, even at the relatively low rates of 1 mm d^{-1} . The net result of the water flow process is to reduce the thickness of the covering soil layer by transporting the compound upward by mass flow.

Effect of Water Content

The chemical property that is principally responsible for volatilization of an organic chemical from a buried soil layer is the effective diffusion coefficient D_E (equation (12)). For the volatile compounds that reside principally in the vapor phase this coefficient is essentially proportional to the 10/3 power of the volumetric air content if one uses the tortuosity model (4) of Millington and Quirk [1961]. For this reason, increasing the water content of the confining layer significantly decreases volatilization flux over any time period. However, it may be difficult to maintain the water content of a landfill or waste repository at a high level, because this requires substantial inputs of water to the site. Because

many of the volatile compounds in Table 1 also represent a potential groundwater threat, application of significant quantities of water may enhance the potential for downward leaching, especially if the repository is not lined effectively at its lower boundary. Thus, in a sense, management for groundwater protection by minimizing water input to the site will tend to maximize volatilization losses by allowing the confining soil layer to dry. This may be particularly harmful to clay liners, which may crack and greatly increase the upward diffusion coefficient in the interlayer between portions of the soil matrix. Thus the optimal management practice for simultaneous groundwater and atmospheric protection may be to apply sufficient water to maintain a high level of water retention without allowing substantial quantities of water in excess of evaporative demand to occur.

CONCLUDING REMARKS

The screening model calculations presented in this paper are intended to evaluate the relative volatility of a large number of compounds, rather than the absolute volatility of a specific compound at a particular site. The 35 compounds evaluated here show a wide range of responses to soil covers of various types and thicknesses, and those compounds that show significant losses from the clayey soil cover of 100 cm are ones for which volatilization should be a cause of concern under general conditions.

The limiting soil cover thicknesses have been calculated under the assumption that the soil layer above the compound induces degradation at the rate characterized by the representative half-life of the compound. However, for those chemicals that require substantial cover thicknesses (e.g., 18 m of sandy soil for Xylene), the assumption of uniform degradation will not be appropriate in soils with shallow microbial activity. What this calculation implies for such compounds, then, is that volatilization is likely whenever the chemical is in the soil, unless the surface is completely sealed.

TABLE 5. Cumulative Volatilization Losses of Chemicals During the First Year After Placement Below 1 m Expressed as a Percent of the Mass Initially Present Between 1.0 and 1.3 m

Compound	Sandy Soil	Clay Soil
Dichlorodifluoromethane	91.3	77.1
Acrolein	85.6	84.7
Xylene	80.2	54.7
Chloromethane	77.0	42.7
1,1,1-Trichloroethane	73.4	21.4
Chloroethene	66.0	37.4
Bromomethane	64.3	30.0
Trichloroethylene	60.0	6.1
Toxaphene	58.3	3.8
Benzene	54.9	6.4
Ethylene dibromide	53.3	3.6
Dichloromethane	52.1	9.9
Chloroethane	44.2	4.8
Chloroform	42.8	4.4
1,2-Dichloroethane	39.9	2.2
1,1-Dichloroethane	27.6	1.0
Methyl ethyl ketone	23.3	3.8
Trichloromethane	20.9	0.4
Methyl isobutyl ketone	13.2	0.7
Toluene	2.6	...
Heptachlor	2.2	...
1,2-dibromo-3-chloropropane	0.2	...

Water Evaporation Rate is 0.1 cm d^{-1}

The assumption of uniform water content, which certainly is greatly in error when the compound must move upward from groundwater, will seriously underestimate the diffusive travel time from a source which must diffuse through a very wet region. However, if this wet region is far below the soil surface, degradation will also be reduced and the compound will survive its passage through the zone and be free to move through the drier soil above.

The model does not include a nonaqueous phase liquid (NAPL) concentration, although many compounds spilled onto soil or present in landfills may be partly found in this form. If the nonaqueous phase can be represented by a simple partition relation similar to that used for the other phases and if transport of the nonaqueous phase is negligible after deposition, then the model may be easily modified to incorporate a NAPL component, with its partition coefficient appearing as an additional chemodynamic property.

Finally, the screening model discussed above may be useful in producing an exposure assessment for individuals living in the vicinity of waste repositories or landfills. Current risk assessments of such locations are conducted with relatively crude models of atmospheric contamination. The flux estimates from this screening model could easily be coupled to a near-atmosphere mixing cell or dispersion model to predict long-term ambient concentrations of volatile pollutants.

APPENDIX A

The cumulative volatilization loss $V_c(t)$ from the soil surface between times 0 and t for a chemical initially deposited between depths 0 and L at concentration C_0 is given by

$$V_c(t) = \int_0^t -J_z(o, t'; L) dt' \quad (A1)$$

where $J_z(o, t; L)$ is given by (18). Note that the minus sign is used because the volatilization flux at the surface, J_z , is negative (opposite in direction to a positive downward z), while the cumulative loss is considered positive. Although this integral may be evaluated numerically, errors may result for volatilization fluxes from chemicals with large K_H unless extremely small intervals of time are used in the numerical integration.

Equation (A1) may be evaluated analytically by a straightforward, albeit tedious, application of the Laplace transform method, with the result

$$\begin{aligned} V_c(t) = & -\frac{C_0}{2} \left\{ \frac{V_E}{\mu} [1 - \exp(-\mu t) \{S_1 - S_2\}] - \frac{(V_E + 2H_E)}{(\mu - \xi)} \right. \\ & \cdot [1 - \exp(-\mu t) \{S_3 - S_4\}] + \exp[-P/2 - \beta(L(D_E t)^{1/2})] \\ & \cdot \left[\frac{(V_E + 2H_E)}{2(\mu - \xi)} - \frac{V_E}{2\mu} - \frac{(V_E + 2H_E)^2}{4(\mu - \xi)\beta(D_E)^{1/2}} + \frac{V_E^2}{4\mu\beta(D_E)^{1/2}} \right] S_5 \\ & + \exp[-P/2 - \beta(L(D_E t)^{1/2})] \\ & \cdot \left[\frac{(V_E + 2H_E)}{2(\mu - \xi)} - \frac{V_E}{2\mu} - \frac{(V_E + 2H_E)^2}{4(\mu - \xi)\beta(D_E)^{1/2}} - \frac{V_E^2}{4\mu\beta(D_E)^{1/2}} \right] S_6 \\ & \left. + \frac{1}{2\beta} \left[\frac{(V_E + 2H_E)^2}{(\mu - \xi)} - \frac{V_E^2}{\mu} \right] S_7 \right\} \quad (A2) \end{aligned}$$

where $P = V_E L/D_E$, $\xi = (H_E - V_E)H_E/D_E$, $\beta = (V_E^2 + 4D_E - \mu)^{1/2}$, and

$$\begin{aligned} S_1 &= \operatorname{erfc} [V_E t / (4D_E t)^{1/2}] \\ S_2 &= \operatorname{erfc} [(L - V_E t) / (4D_E t)^{1/2}] \\ S_3 &= \exp(\xi t) \operatorname{erfc} [(V_E - 2H_E) t / (4D_E t)^{1/2}] \\ S_4 &= \exp(\xi t + H_E L/D_E) \operatorname{erfc} [(L - (V_E \\ &+ 2H_E) t) / (4D_E t)^{1/2}] \\ S_5 &= \operatorname{erfc} [L / (4D_E t)^{1/2} - \beta(t)^{1/2}] \\ S_6 &= \operatorname{erfc} [L / (4D_E t)^{1/2} + \beta(t)^{1/2}] \\ S_7 &= \operatorname{erf} [\beta(t)^{1/2}] \end{aligned}$$

The cumulative volatilization $V_{c,b}(t)$ of a chemical initially incorporated between L and $L + W$ is

$$V_{c,b}(t) = V_c(t; L + W) - V_c(t; L) \quad (A3)$$

Details of the derivation of (A2) are available upon request.

APPENDIX B

As shown by Jury *et al.* [1984a], compounds with large K_H are insensitive to the thickness of the boundary layer. Therefore the volatilization solution (18) with $H_E \rightarrow \infty$ will describe the behavior of these compounds adequately. For the case of zero water evaporation ($V_E = 0$) and zero boundary layer thickness ($H_E \rightarrow \infty$), (18) becomes

$$J_z = C_0 e^{-\mu t} (D_E / \pi t)^{1/2} [1 - \exp(-L^2 / 4D_E t)] \quad (B1)$$

where the approximation

$$\operatorname{erfc}[x] = \frac{1}{(\pi)^{1/2}} \frac{e^{-x^2}}{x} \quad (B2)$$

has been used to expand the error function for large x [Carslaw and Jaeger, 1959].

Thus the volatilization flux from a buried layer of chemical located initially between $z = L$ and $z = L + W$ is

$$\begin{aligned} J_z^b = & -C_0 e^{-\mu t} (D_E / \pi t)^{1/2} (\exp(-L^2 / 4D_E t) \\ & - \exp[-(L + W)^2 / 4D_E t]) \quad (B3) \end{aligned}$$

The total mass fraction $V_c^b(\infty)/M_0$ volatilized in infinite time is then

$$\begin{aligned} V_c^b(\infty)/M_0 = & \frac{1}{W} \int_0^\infty \left(\frac{D_E}{\pi t} \right)^{1/2} \exp(-\mu t) \\ & \cdot \{ \exp(-L^2 / 4D_E t) - \exp[-(L + W)^2 / 4D_E t] \} dt \quad (B4) \end{aligned}$$

where $M_0 = C_0 W$ is the initial mass.

If we make the substitution $y = t^{1/2}$, (B4) becomes

$$\begin{aligned} V_c^b(\infty)/M_0 = & \frac{2}{W} \left(\frac{D_E}{\pi} \right)^{1/2} \int_0^\infty \exp(-\mu y^2) \{ \exp(-L^2 / 4D_E y^2) \\ & - \exp[-(L + W)^2 / 4D_E y^2] \} dy \quad (B5) \end{aligned}$$

Making use of the well known definite integral

$$\int_0^{\infty} \exp(-ay^2 - b/y^2) dy = \frac{1}{2}(\pi/a)^{1/2} \exp[-2(ab)^{1/2}] \quad (B6)$$

[Abramowitz and Stegun, 1970]. (B5) becomes

$$\frac{V_c^b(x)M}{M_o} = \frac{1}{W} \left(\frac{D_E}{\mu} \right)^{1/2} \exp[-L(\mu/D_E)^{1/2}] [1 - \exp[-W(\mu/D_E)^{1/2}]] \quad (B7)$$

which approaches

$$\frac{V_c^b(x)M}{M_o} = e^{-L(\mu/D_E)^{1/2}} \quad (B8)$$

for small W . Hence the fractional cumulative volatilization loss of chemical in a narrow band a distance L below the surface is given by (B8). Thus to minimize $V_c^b(x)/M_o$,

$$L \gg (D_E/\mu)^{1/2} \quad (B9)$$

Values of $L = 5(D_E/\mu)^{1/2}$, which lower $V_c^b(x)/M_o$ to 0.007, are calculated in the text as examples of the limiting soil cover. Equation (B9) will underestimate the mass loss when evaporation is present.

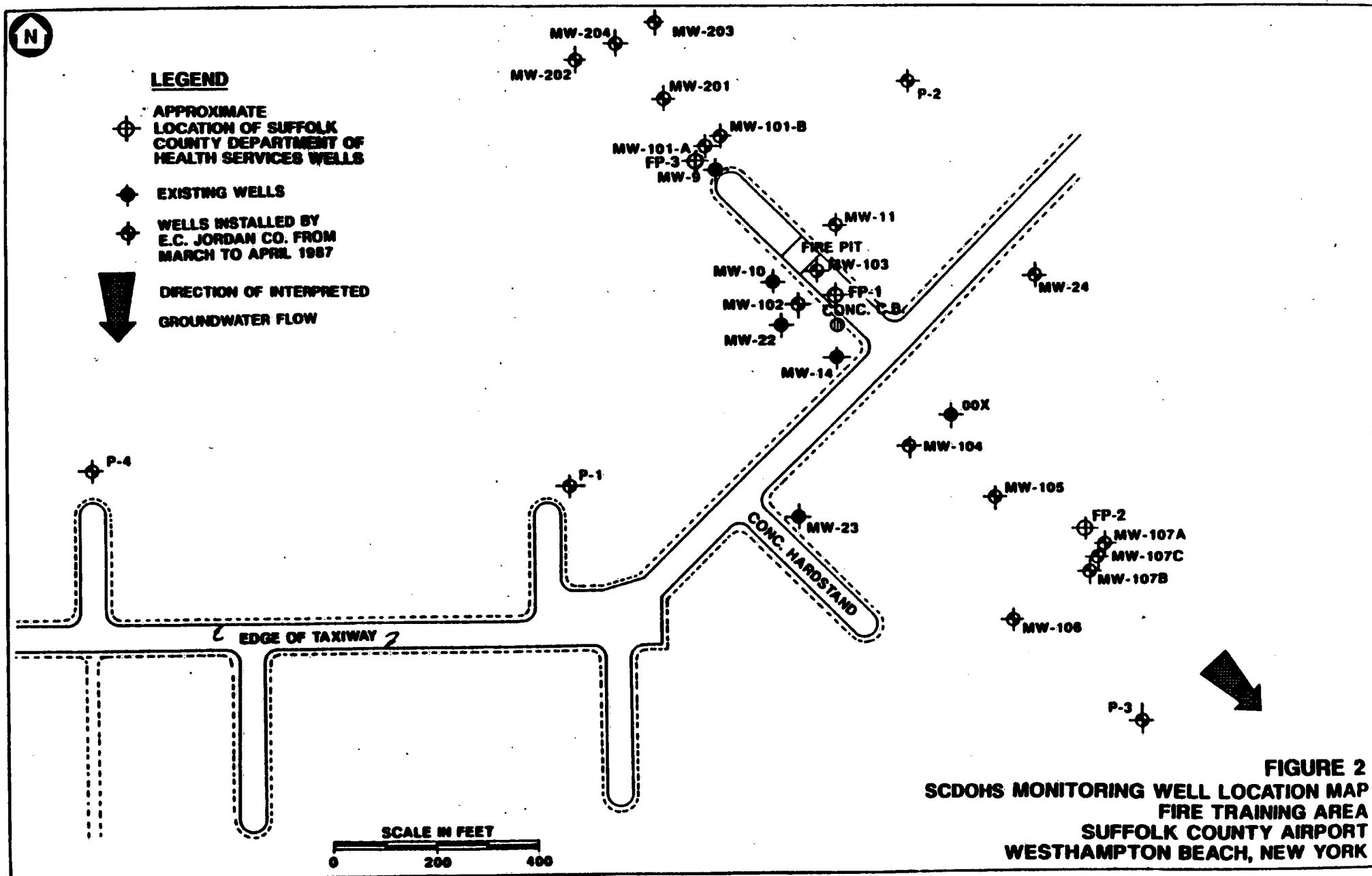
Acknowledgment. The authors would like to thank the California Department of Health Services for financial support of the research discussed in this project.

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accepted July 20, 1989.)

ATTACHMENT O



Lab No. 493110
Field No. C-EP-1
Date 4-13-93
Time 10:05 PM GH
Col. by 2 MILITARY

Rec'd at Lab 4-12-93
Public Water
Private Well
Other
Exam. by 4-15-93

SUTTER COUNTY DEPARTMENT OF HEALTH SERVICES
PUBLIC HEALTH LABORATORY
DIVISION OF MEDICAL LEGAL INVESTIGATIONS & FORENSIC SCIENCE
TRACE ORGANIC ANALYSIS OF WATER

WYS Well: EP-1

Sample Raw ☒ Treated ☐

Name TEST WELL

Tap: Well ☒ Tank ☐

No. & Street WEST HAMPTON AIRPORT

File # Box # Ct #

Village WEST HAMPTON

Other

Number of sample vials submitted 2

PLEASE RUN FOR MEK

DBP	Compound	DBP	DBP	Compound	DBP
305	vinyl chloride		250	benzene	
306	methylene chloride		251	toluene	6
323	1,1 dichloroethane ...		252	chlorobenzene	
309	trans 1,2 dichloroethane		253	ethylbenzene	
300	chloroform		254	o-xylene	
324	1,2 dichloroethane ...		252	m-xylene	
321	1,1,1 trichloroethane		253	p-xylene	
304	carbon tetrachloride .		255	total xylene	
294	1 bromo 2 chloroethane		256	2-chlorotoluene (o)	
405	1,2 dichloropropane ..		257	m-chlorotoluene	
310	trichloroethane		258	4-chlorotoluene (p)	
303	chlorodibromomethane .		259	total chlorotoluene	
293	1,2 dibromoethane		419	1,3,5 trimethylbenzene	
420	2 bromo 1 chloropropane		418	1,2,4 trimethylbenzene	
301	bromoform		415	m,p-dichlorobenzene	
311	tetrachloroethane		412	1,2 dichlorobenzene (o)	
308	cis 1,2 dichloroethane		432	p-diethylbenzene	
320	freez 113		413	1,2,4,5 tetramethylbenzene .	
292	dibromomethane		437	1,2,4 trichlorobenzene	
307	1,1 dichloroethane ...		438	1,2,3 trichlorobenzene	
302	bromodichloromethane .		600	ethenylbenzene (styrene) ...	
406	2,3 dichloropropane ..		601	1 methylethylbenzene (m-xylene)	
407	cis dichloropropane ..		602	n-propylbenzene	
408	trans dichloropropane		603	tert-butylbenzene	
322	1,1,2 trichloroethane		604	sec-butylbenzene	
409	1112 tetrachloroethane		605	isopropyltoluene (p-xylene)	
295	s-tetrachloroethane ..		606	n-butylbenzene	
433	1,2,3 trichloropropane		607	hexachlorobutadiene	
450	2,2 dichloropropane ..		608	1,2 dibromo 3-chloropropane	
451	1,3 dichloropropane ..		***	methyl-tertiary-butyl-ether	

619 2-Butanone (MEK) 410

Result for each organic compound listed above is (0.5ppb except, where noted.

Lab No. 493111
Field No. S-EP-2
Date 4-12-93
Time 3:57 PM
Col. by R. MILLER

Rec'd at Lab 4-12-93
Public Water
Private Well
Other
Exam. by JL 4-15-93

SUTTER COUNTY DEPARTMENT OF HEALTH SERVICES
PUBLIC HEALTH LABORATORY
DIVISION OF MEDICAL LEGAL INVESTIGATIONS & FORENSIC SCIENCE

TRACE ORGANIC ANALYSIS OF WATER

NYS Well # FR-2

Sample Raw ☒ Treated ☒

Name TEST WELL

Tap: Well ☒ Tank ☐

No. & Street WEST HAMPTON AIRPORT

Village WEST HAMPTON

Number of sample vials submitted 2

DBP	Compound	DBP	Compound
305	vinyl chloride	250	benzene
306	methylene chloride	251	toluene
323	1,1 dichloroethane	252	chlorobenzene
309	trans 1,2 dichloroethane	253	ethylbenzene
300	chloroform	254	o-xylene
324	1,2 dichloroethane	252	m-xylene
321	1,1,1 trichloroethane	253	p-xylene
304	carbon tetrachloride	255	total xylene
294	1 bromo 2 chloroethane	256	2-chlorotoluene (o)
403	1,2 dichloropropane	257	m-chlorotoluene
310	trichloroethane	258	4-chlorotoluene (p)
303	chlorodibromomethane	263	total chlorotoluene
293	1,2 dibromoethane	419	1,3,5 trimethylbenzene
420	2 bromo 1 chloropropane	418	1,2,4 trimethylbenzene
301	bromoform	413	m,p-dichlorobenzene
311	tetrachloroethane	412	1,2 dichlorobenzene (o)
308	cis 1,2 dichloroethane	432	p-diethylbenzene
320	freon 113	435	1,2,4,5 tetramethylbenzene
292	dibromomethane	437	1,2,4 trichlorobenzene
307	1,1 dichloroethane	438	1,2,3 trichlorobenzene
302	bromodichloromethane	600	ethenylbenzene (styrene)
406	2,3 dichloropropene	601	1 methyl ethylbenzene (cumene)
407	cis dichloropropene	602	n-propylbenzene
408	trans dichloropropene	603	tert-butylbenzene
322	1,1,2 trichloroethane	604	sec-butylbenzene
409	1112 tetrachloroethane	605	isopropyltoluene (p-cymene)
295	s-tetrachloroethane	606	n-butylbenzene
433	1,2,3 trichloropropane	607	hexachlorobutadiene
450	2,2 dichloropropane	608	1,2 dibromo 3-chloropropane
451	1,3 dichloropropane	***	methyl-tertiary-butyl-ether

6/91 2-Butanone (MEK) 410

Result for each organic compound listed above is <0.5ppb except where noted.

Lab No. 493112
Field No. S-EP-3
Date 4-12-93
Time 12:10 PM
Col. By R. M. L. T. (PH)

Rec'd as Lab 4-12-93
Public Waste
Private Well
Other
Exam. By J. L. 4-15-93

SUTTORF COUNTY DEPARTMENT OF HEALTH SERVICES
PUBLIC HEALTH LABORATORY
DIVISION OF MEDICAL LEGAL INVESTIGATIONS & FORENSIC SCIENCES

TRACE ORGANIC ANALYSIS OF WATER

WYS Well # EP-3

Sample Raw ☐ Treated ☒

Name TEST WELL

Tap: Well ☒ Tank ☐

No. & Street WEST HAMPTON AIRPORT

Village WEST HAMPTON

Number of sample vials submitted 2 PLEASE RUN MEK

DBP	Compound	DBP	Compound
305	vinyl chloride	250	benzene
305	methylene chloride	251	toluene
323	1,1 dichloroethane	252	chlorobenzene
309	trans 1,2 dichloroethane	253	ethylbenzene
300	chloroform	254	o-xylene
324	1,2 dichloroethane	252	m-xylene
321	1,1,1 trichloroethane	253	p-xylene
304	cis-1,2 dichloroethane	253	total xylene
294	1-bromo 2-chloroethane	266	2-chlorotoluene (o)
405	1,2 dichloropropane	267	m-chlorotoluene
310	trichloroethane	268	4-chlorotoluene (p)
303	chlorodibromomethane	263	total chlorotoluene
293	1,2 dibromoethane	419	1,3,5 trimethylbenzene
420	2-bromo 1-chloropropane	418	1,2,4 trimethylbenzene
301	bromoform	415	m,p-dichlorobenzene
311	tetrachloroethane	412	1,2 dichlorobenzene (o)
308	cis 1,2 dichloroethane	432	p-diethylbenzene
320	freon 113	435	1,2,4,5 tetramethylbenzene
292	dibromomethane	437	1,2,4 trichlorobenzene
307	1,1 dichloroethane	438	1,2,3 trichlorobenzene
302	bromodichloromethane	600	ethanylebenzene (styrene)
406	2,3 dichloropropene	601	1-methylethylbenzene (cumene)
407	cis dichloropropene	602	n-propylbenzene
408	trans dichloropropene	603	tert-butylbenzene
322	1,1,2 trichloroethane	604	sec-butylbenzene
409	1,1,2 tetrachloroethane	605	isopropyltoluene (p-cymene)
295	s-tetrachloroethane	606	n-butylbenzene
433	1,2,3 trichloropropane	607	hexachlorobutadiene
450	2,2 dichloropropane	608	1,2 dibromo 3-chloropropane
451	1,3 dichloropropane	***	methyl-tertiary-butyl-ether

6/9: 2-Butanone (MEK) <10.

Result for each organic compound listed above is <0.5ppb except where noted.